THE ROLE OF TECHNOLOGY IN THE FAILURE OF THE RIGID AIRSHIP AS AN INVENTION

By

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MONETARY CONVERSION TABLE

For the sake of convenience, I have left the sums of money cited in this paper in terms of national currency. For most of the period covered (except for the postwar German inflation that made the mark virtually worthless in November, 1924), the following conversion table approximates the exchange rate for Britain and Germany with the United States:

British pound	-	$4.80 U. S.
German mark	-	.25 U. S.

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The prominence of technology in Western society has been recognized by such prominent social scientists as Arnold J. Toynbee and Pitirim A. Sorokin. Although these men disagree as to the actual significance of technology, both recognize the importance of the role of invention in technology. S. Colum Gilfillan has analyzed the inventive process, demonstrating that the success of an invention is dependent on a combination of factors. This combination of factors has been examined many times from the viewpoint of its effect on a successful invention. An examination of the combination of factors from the

perspective of its effect on an invention that failed, however, provides an otherwise unobtainable opportunity to investigate the nature of each of these factors and determine which were ultimately responsible for causing the invention to fail.

In the field of transport, the rigid airship is generally considered to be an invention that failed. Yet of all the technological responses to the challenging problem of flight in the early 20th century, only the rigid airship seemed to provide a means of large capacity long distance transportation. Why did it fail?

Of necessity, an examination of the forty years of development of this invention in context covers a wide range of the factors mentioned above. Nevertheless, it is possible to investigate each without isolating it from its relationship with the others. For example, in the period of experimental development before 1908, the lack of financial backing caused Count von Zeppelin to abandon his work on airships on two occasions. Eckener overcame this problem by making the rigid airship the subject (and a symbol) of German national pride. The rigid airship became the only transport invention financed by public contributions. During World War I, the main challenge facing the airships of the German Naval Division was competition from the rapidly developing airplane. The War gave great impetus to the dif-

fusion of rigid airship technology, which had been a virtual German monopoly; this process of technological difiusion culminated when the Allies took what was left of the German naval airship fleet and divided it among themselves.

However, the attempts after the War to continue a rigid airship program in Britain, to establish one in France and the United States, and to re-establish one in Germany all foundered on the same rock that had plagued the rigid airship from the very beginning: technological inadequacy. Because the technology of the airship was imperfectly understood, the postwar attempts to use military or civil airship transport could not be freed of the onus of disaster. The _R 38_, the _Dixmude_, the _Shenandoah_, the _Akron_, and the _Macon_--all were lost due to technological shortcomings.

Governments formerly willing to support airship development could not continue to do so in the face of the often spectacularly gruesome disasters that were headline news. Thus, because additional financial backing was not forthcoming, the technological challenge could not be met. The rigid airship stood condemned not in principle but in practice.

CHAPTER I

INTRODUCTION

Some Forethoughts on the Process and Diffusion of Invention

The process of invention, which is generally regarded in the West as one of the prime movers of change, occupies a central position in our society. To the sociologist, Pitirim A. Sorokin, technological invention "comprised the most productive and basic field of our modern culture."[1] While few would deny this, there is, nevertheless, little agreement concerning the circumstances in which technological invention and innovation take place.

According to Sorokin invention has achieved the importance in Western culture that it has only because this culture happens to be past the zenith of its sensate stage of development, in which empiricism is the determinant of truth.[2] As we move deeper into the twilight of this particular sociocultural paradigm, technological invention will become less and less capable of solving problems and placating needs because the cultural pattern will no longer provide the proper nourishment for further development in this area. The relationship between Western

culture and the acceptance and adoption of technological invention is therefore strictly a causal one, making our civilization different in quantity but not in kind from those that have gone before.

In distinct contrast to the views of Sorokin, the historian Arnold J. Toynbee sees technological invention and innovation as a societal force without parallel in the histories of other civilizations.[3] By providing the means whereby Western man has mastered his environment technological invention and innovation has compounded and accelerated the rate of social change so dramatically that Western civilization might best be described as a society of subsocieties in constant and permanent ferment. The process of invention and Western civilization mutually interact to produce a society without precedent.

Sorokin and Toynbee are but two of the many scholars whose attention have been drawn to technological invention and who concern themselves to understand its working and ramifications from several perspectives, including the origins, diffusion, and especially the commercial success of inventions.

It is to the latter aspect--the acceptance or rejection of an invention--that we have addressed ourselves in this dissertation. For the rigid airship--the topic of this dissertation--is generally regarded as one of the classical "failures" of invention and innovation. By 1908, the first

practical rigid airship was flying regularly; by 1914, the Zeppelin airships had carried more than 10,000 passengers and completed 107,000 miles during 1,588 flights without mishap;[4] by 1918, the dirigible had proven its worth as a sea scout and had executed military feats without comparison; by 1921, every major Western power (except Russia) had the beginnings of an airship fleet; by the early '30's, regular transatlantic flights were being made. And then? And then, just when it seemed that the dirigible's future was assured, there was a reverse of fortune which by 1940 had carried the last great dirigible to the scrapheap. Our own interest in the airship began years ago. In writing this dissertation we have tried to answer a question that has plagued us personally: how did it come about that what might have been such a brilliant success should have proved to be such a spectacular failure?

Despite its rather obvious importance, the question of why some inventions succeed while others do not in any given society has elicited very little in the way of scholarly attempts to provide a detailed answer. To place one's trust in such explanations as "necessity is

the mother of invention" is to avoid differentiating among the whole multitude of postulates upon which a society exists as well as the myriad of forces operating within that society.

S. Colum Gilfillan, in his fundamental study of the interplay of societal forces and the process of invention, points out that an invention has an essentially evolutionary nature; it is the product of the application of previous experience to new and different situations to bring into existence, either by design or by chance, something new and useful.[5] But this prior experience, even though it is taken apart and reassembled much in the manner of building blocks, is still a manifestation of the civilization that produces it because cultural techniques cannot be dissociated from the group of conceptions, the sociocultural paradigm, that produced them. No civilization can produce inventions totally without connection to its own sociocultural heritage, and the introduction by others of inventions alien to a given culture has historically led to comparatively massive upheaval in, if not outright destruction of, that culture.

History is replete with examples of this simple truth. No one perhaps was more aware of it than the Indian leader Mahatma Gandhi, whose resultant attempts to reverse the industrialization of Indian textile manufacture nevertheless proved futile.[6]

Profoundly disrupting inventions can come from within a society as well as from without. In 1835 the editor of a British journal warned that railroads would "give an unnatural impetus to society, destroy all the relations which exist between man and man, overthrow all mercantile regulations, and create, at the peril of life, all sorts of confusion and distress."[7] At the time, he was probably considered to be somewhat of a stuffy conservative--a generation later, ludicrously so. The fact that he was almost totally correct was essentially meaningless at that time, for the world he sought to preserve was gone.

Whether new techniques may penetrate cultures more easily than new ideas is an open question on which both Sorokin and Toynbee, among others, have had much to say. Sorokin advocates that ideas may transfer more readily than techniques, based upon two arguments. An idea can pass from individual to individual and undergo modification faster, thus making it seem less alien. Secondly, ideas may become sufficiently mutated to serve a purpose entirely different from that which spawned it.[8] These factors promote ease of transmission and adaptability in function.

Toynbee argues that techniques can pass from one civilization to another because they can be absorbed, in limited numbers, with little or no reference to the culture of origin.[9] To borrow Sorokin's concept of a civilization

being composed of a set of congeries as well as systems of ideas and techniques, the borrowing civilization might incorporate the new technique into an already extant system, as, for example, a new military tactic which might be learned. Another possibility is that the civilization might use the technique without reference to any system: that is, as a congeries. However, unlike ideas, techniques are seldom sufficiently mutable to serve different purposes in different societies. Although a technique may be adopted by a civilization that is "ready" for it, another may be completely ignored, if the cultural patterns of that civilization impede its entry and assimilation.

If an innovation lacks relevancy to the needs of a civilization it will either pass into oblivion or be utilized in an entirely different way. The wheel is one of the prime basic components of contemporary culture, but archeological finds indicate that early northern Europeans thought of it only as a handy device to make opening or closing a gate easier and the Incas regarded it as a toy of sufficient interest to amuse the very young.

Nevertheless, this does not imply that both ideas and techniques may not be adopted out of their original contexts, channeling thought and effort into new areas heretofore denied or neglected in the development of the adopting civilization. Because the redirecting process

takes place within the framework of a new context, however, the end product usually bears little resemblance to its original source.

Because an invention is evolutionary in nature and because cultures tend to develop along similar lines and encounter similar problems, it is not surprising that many of the same technological innovations have been invented at different times in different civilizations or simultaneously in different parts of one civilization. If knowledge of a problem requiring a technical innovation for solution pervades a large segment of a society, then it is likely that several different inventions, quite possibly based upon dissimilar principles and not resembling each other in the least, will be produced in response.

The sociologist, Matthew Melko, has observed that civilizations absorb ideas and techniques in proportion to three factors, given in order of declining importance: their relevancy to problems encountered by the adopting civilization; the civilization's receiving capability; and the force of the presentation.[10] Although written in reference to the societal assimilation of material of external origin Melko's criteria relate equally well to the reception of ideas and techniques produced within. Whether an invention springs from the creative mind of

a native son or had to be imported from a distant shore seems to make very little difference; a relevant innovation will be incorporated, an irrelevant one will not.

If the various systems and congeries of a culture are in relative harmony with each other, it is in a state of stability that discourages the adoption of new ideas and techniques involving change, and the momentum of that stability will persist until some cataclysmic event occurs. A society in flux, however, tends to accept innovations in any of its institutions more readily regardless of their point of origin because of the systemic interconnection of all the institutions of that society; the shifting and re-coalescing of the composition of one effects adjustments in the others as well. This was clear to the British journal editor who made the prediction concerning the consequences of the construction of the railroad: a change in the system of land transportation would bring about changes in "the pace of life," societal relationships and commerce, to say nothing of the demise and restructuring of other institutions about which he could not even guess.

Toynbee assigns force of presentation a considerably more important role than Melko does in his arguments.[11] As they both write about it in the context of one civilization affecting another, such factors as distance, communication, and (especially for Toynbee) the internal

condition of the projecting society are relevant points of importance. In terms of the assimilation of technological inventions from within, however, only communication retains its importance. If an innovation is produced in an isolated area, it is unlikely to have much of an impact on the society as a whole. The multiplicity of invention at any given time, however, as Gilfillan points out, nullifies this possibility to a large degree.

Other factors arise to displace distance and the internal condition of the projecting society. There must exist the prerequisite technical ability to produce it in the quantity needed, a means of working with it, a method of making it known to potential users, financial backing and management, public willingness to accept (at least to a certain extent), and, in some cases, accumulated capital in the form of extant plant and other facilities. So essential are these preconditions that Gilfillan includes most of them in his definition of an invention.[12]

Moreover, each of these has its own elemental parts, any of which if modified alters drastically the degree to which an invention is acceptable to a society; the absence or even the presence of one of these elements in an alternatively developed form will have a definite effect on the success or failure of a given invention.

One often reads or hears of an invention that was, or is, "ahead of its time." Although this is a rather

vague phrase that can mean several things, it aptly fits the situation where someone conceives an idea the implementation of which lies beyond the technical capabilities of his society and epoch. It may even be that working prototypes can be constructed but that because of expense, inadequacy of materials, or general unreliability the invention never achieves acceptance. Similarly, if there is no means of working with the invention, then it cannot be adopted.

For any innovation to succeed, it must be exposed to those who might reasonably be interested in using it; consequently, there must exist some means of doing this, either through demonstration, advertisement, or notoriety. The Wrights put their machine into the air in December, 1903, yet it was not until almost five years later that they were able to interest a potential buyer in it. Usually, too, this necessity of promoting the invention through advertising or demonstrating it at least several times is but one of a large number of expenses that occur. Additionally there may also be the costs of constructing various models and conducting tests (an expensive matter when they are full-scale models), as well as obtaining working room and paying whatever staff is required. Some sort of financial backing, therefore, must be found. As the bankrolling of an invention is likely to be provided

by a party already having a substantial investment of accumulated capital in the general field of the invention, it will perforce dovetail with the equipment representing that capital.

Inadequate presentation is the reason (plus the lack of public acceptance of the idea) why the backers of coast-to-coast unit trains of containerized cargo do not seem to be able to "sell" their idea in the United States today. Existing plant consists of box cars, not container flats; mixed freights, not unit trains; and several rail lines, each jealous of its share of the fee. The "public" ranges from staunchly conservative railroad presidents to unionized crew men whose inflexible work rules make it difficult for such a train to be adopted. So one of the innovations that might provide the salvation for the moribund American railroads languishes in limbo.

Moreover, few important inventions have been adopted without entrepreneurial promotion. Electrical telegraphy was invented simultaneously by several different men, but Samuel F. B. Morse is the name most closely connected with this innovation because he was able to lobby Congress for the appropriation that initiated acceptance of his system. Like Edison, he was unusual in that he was both inventor and entrepreneur. In most cases, the entrepreneur undertakes the promotion of an invention created by someone

else. In this connection, one has but to think of the necessary relationship between Watt and Boulton or Howe and Singer. Likewise, a rapid projection of the invention is vital to its adoption. No one is going to advocate or take up an invention if another serving the same purpose is already in widespread use.

Indeed, the complexity and diversity of the factors upon which depend the success or failure of an invention make it difficult to give specific reasons why one invention succeeds and another fails; perhaps because of this, the attempt is rarely made. Nevertheless, some factors do have greater significance than others in the birth, life, and death of an invention. For some inventions there are factors of such a critical nature that they are, in effect, the _sine qua non_ for the success of those inventions. In the case of the rigid airship we are convinced that technology (as it applied to the materials and the techniques used in the construction and maintenance of aircraft) was the decisive factor determining the at least temporary rejection of this form of transport. Yet we hasten to add that technology (although of paramount importance) cannot be the ultimate determining factor for any invention in and of itself, for technology is but a facilitative device by means of which a society expresses its values. To state that technology was the insurmountable impediment to the general adoption of the

rigid airship is to raise the question why society, either in groups or individually, did not persevere and overcome the problems involved--a question that cannot be answered without inquiring into a society's system of values and cultural orientation.

Of the Airship Itself: A Technological Primer

To say that the acceptance or rejection of the dirigible depended upon technological factors is meaningless unless we provide at least an outline of the technical features of the invention we are discussing. To this end, we shall begin our investigation by first setting down the characteristics of the three types of aeronautical vehicles generally classed as airships: (a) non-rigids, (b) semi-rigids, and (c) rigid frame. As the greatest attention in these pages will be given to the rigid airship, it is necessary and desirable that we should enlarge upon its technical details.

The principal determinant that makes a dirigible balloon an airship is that the latter has been shaped in some manner to provide the least resistance to motion through the air in the desired direction. The constructional

method of determining and maintaining this shape is the means whereby each airship may be classified as non-rigid, semi-rigid, or rigid.

The non-rigid airship, commonly called the blimp, consists of a gasbag from which is suspended usually one car for both the crew and the engine or engines. Such an airship has only a small capacity for gas and hence little lifting power, a problem aggravated by the inability of the gasbag (or envelope) to resist very large shear or bending forces. The shape of the gasbag depends primarily on the pressure of the lifting gas it contains; thus, the ability of the blimp to make headway after descending from a high altitude is seriously impaired because the increased atmospheric pressure causes the envelope to lose its desired shape and offer more resistance unless the increased atmospheric pressure is offset by pumping air into separate compartments in the gasbag to increase internal pressure. Likewise, the use of gas pressure to maintain the shape of the envelope severely limits the top airspeed as it is quite possible that the nose of the blimp might be flattened or even blown inward should the external pressure there become too great.

The second type of airship (unlike the blimp which was used by virtually every major nation) found greatest acceptance as an airship design in Italy. It is essentially a blimp stiffened by a keel running most, if not

all, of the length of the base of the envelope. While this keel offers greater resistance to the shear and bending forces (thus increasing the carrying capacity of the semi-rigid), it also permits (because of the longitudinal stiffening of the bag) an airship to be built larger and to fly faster than the non-rigid type.

The largest type of dirigible is the rigid airship. The containers of the gas that provide the lifting power are held in a rigid structure that maintains the shape of this type of airship; in addition, the frame resists both shear and bending forces as well as gas and air pressure. Hence, the form of the ship remains unaffected by either high speeds or loss of gas in one of the compartments.

The two principal components of the external framework of the rigid airship are (a) the transverse frames, polygonal "rings" of straight girders, the number of which is determined by the designer as the number of sides the ship will have, and (b) the longitudinal girders that, by means of fixed joints, hold these frames a predetermined distance apart, forming "bays" between the frames. Of these girders, only those at the very front of the ship, known as the bow cap, are curved. Steel wire diagonally braces the rectangular panels formed by the girders and frames. Additional wires, called radial wires, brace the joints of alternate (or every third)

transverse frames to a central axial cable running the length of the ship to prevent any possible distortion of the frame. All metal parts have a coat of resin-based varnish to prevent corrosion.

This tubular skeleton structure, rounded at the bow and tapered aft to produce a streamlined form, supports an outer cover of doped fabric made in sections with eyelets for lacing together. Fins at the tail section to provide longitudinal stability and support for the rudders and elevators are also covered with doped fabric.

The lifting gas is contained in separate compartments, each of which occupies one of the chambers formed by the hull of the ship and two of the transverse frames with radial wire bracing. As a safety measure designed to reduce the conduction of the heat of the sun to the gas, there is a built-in gap between the bag and the hull. The bag of each compartment, with some variation from ship to ship, is generally made of cotton fabric coated on the inside with rubber. This coat of latex becomes the adhering agent for an extremely thin membranous material, either goldbeater's skin or a synthetic substitute, which in turn receives a coat of waterproofing agent. A special tape secures the seams of the bag as well as the joints around both the automatic and the manual valves, which empty into vertical exhaust passages.

Access to all sections of the ship is provided by the corridor that passes through the length of the airship at its keel. The longitudinal framework around this corridor supports whatever load the airship carries and furnishes the location for the fuel tanks, crew's quarters, bags of water ballast, and the payload. This corridor also gives entry to the control cabin. Although not precisely the same in every airship, the control cabin or car from which the commander navigates the ship is generally forward of midships and is built into or suspended from the section of girderwork that forms the keel of the vessel (see diagram next page).

Usually four to six gasoline engines provide the propulsive power for a rigid airship. Suspended or located inboard in pairs on the underside of the vessel, these engines drive two-bladed push propellers. In addition to horizontal movement, a skillful commander could also obtain some aerodynamic lift (in addition to the aerostatic lift provided by the gas) from these engines by using the rudders to put the ship up at the bow.

The preceding passages have described the rigid airship at its highest stage of development; as initially conceived, it differed considerably from this in many respects, even as the role for which it was invented

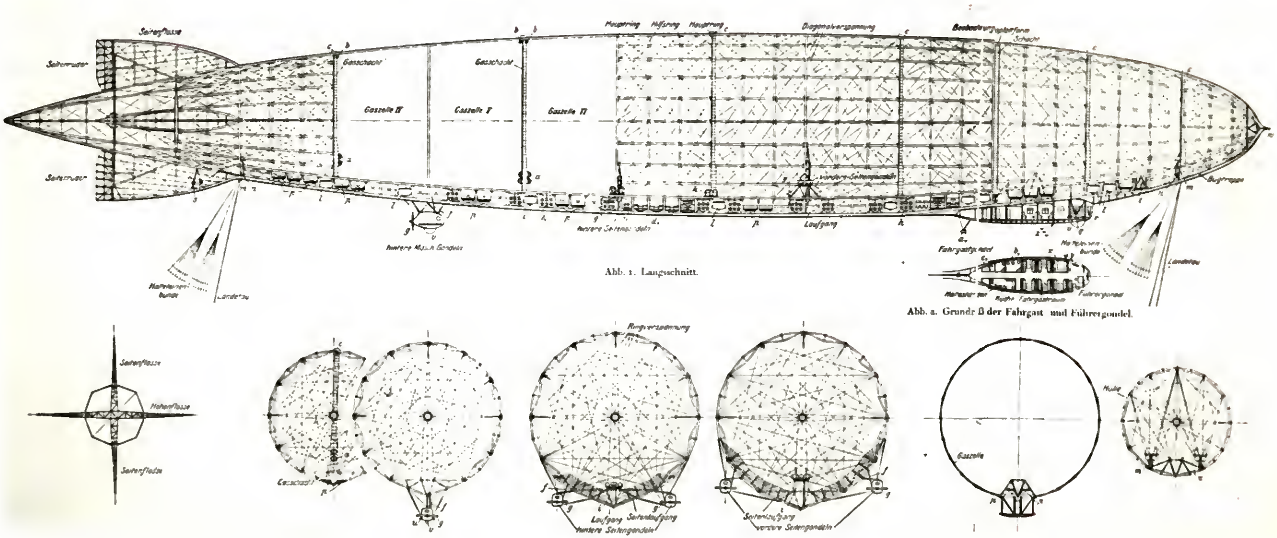

Figure 1: Diagrams of the rigid airship LZ 126 (ZR 3 Los Angeles) illustrating the framework of longitudinal girders, transverse frames, and wire bracing.

differed from that in which it achieved its greatest comparative success.

The Rigid Airship Considered Against the Background of Previous Developments in Transportation

Prior to the 19th century, the ability of men to take their goods or themselves from one place to another was largely restricted to the methods used since ancient times.

The single significant advance in land transportation since the advent of the Roman road was the draught collar that permitted the domesticated beast to pull a larger load without strangling itself; yet this was of little or no value for transportation outside small areas of Europe where the Roman roads remained usable. The principal method of cross-country transport remained pack animals. Most bulk goods were shipped on watercourses, The increasing volume requiring overland transport made the construction of canals and turnpikes feasible on a national scale in the second half of the 18th century. Nevertheless, transportation costs remained high and the natural obstacles that hindered the movement of commerce and restrained economic activity remained.

The application of steam power in the 1800's to land transportation, in the form of railroads, made long-distance overland carriage practical in Europe and North America. Europeans and Americans exported railroads with almost as much enthusiasm as they built them for themselves. The colonization and economic penetration of Asia, Africa, Australia, and Latin America brought railroads in its wake; they were the primary means Europeans used to direct the economic development of these areas along the parallel lines of steel that connected the producers of bulk commodities with markets.

But this extension of railroad lines in continents other than Europe, North America, and to a lesser extent, Asia, depended to a growing degree on a concurrent transformation of the method of propulsion in yet another field of transportation: oceanic carriage.

Although the overall effect of steam engines on oceanic travel was less dramatic than that of the advent of the locomotive and flanged wheel on land, it obviously was of fundamental importance. Although paddle-wheeled riverboats quickly established their worth upon the rivers of North America, the somewhat primitive and awkward engines of their early oceanic equivalents prohibited them from competing with the relatively efficient sailing vessels of that period. Subject to chronic mechanical failure and unable to carry a profitable cargo and

sufficient fuel for their engines, early steamships were not commercial successes. Nevertheless, their superior speed was noted, and, as this feature became important with the establishment of scheduled packet lines, craft with both steam engines and sails gradually displaced those relying upon sails alone. This trend was hastened through the adoption of iron and then steel for the hull, thus making possible the construction of larger, stronger, lighter, more durable hulls that were more resistant to decay.

In time, screw propellers supplanted paddle wheels entirely while compound triple- and quadruple-expansion high-pressure engines reduced fuel consumption considerably. With greater regularity, dependability, and falling costs, steam-powered vessels slowly but steadily displaced their wind-powered predecessors until by 1900 over 60 per cent of the world's recorded shipping fleets were steam vessels and the last major sailing ships were losing their places on the wool and wheat run to Australia as well.

Not only did greater speed and regularity on land and sea reduce the cost of shipping traditional bulk cargoes such as grain, fibers, and minerals; of equal importance is the fact that they also made it possible to carry heretofore prohibited perishable goods. Shipping cattle from the grasslands of Texas and the ranges in the

western United States to meat-packing plants in Kansas City or Chicago and the prepared meat from there to markets along the east coast became quite profitable; as did, for instance, the construction of railroads to bring such a perishable item as the banana to the Atlantic coast of Central America.

Notwithstanding the great changes wrought by the application of steam power to transportation, significant drawbacks still existed, especially on land. Railroads had to follow a winding watercourse or the often-contorted natural contours of the land. Swamps and mountains barred their paths. Moreover, building railroads was a tremendously expensive undertaking. In a combined water-land shipping operation the tediously slow on- and off-loading of goods was unavoidable. The answer, of course, to some of these problems, was to take to the air. But then, to do that required a conjunction of circumstances only some of which were favorable (not least the unprecedented expansion of the world economy). There were better things to do with one's money in the 19th century than put it behind the dreams of those few visionaries who saw a great deal of man's destiry unfolding not on the earth and the seas but in the sky.

NOTES

1. Pitirim A. Sorokin, Social and Cultural Dynamics, Vol. II (New York: Bedminster Press, 1962), p. 169.

2. Ibid., p. 180.

3. Arnold J. Toynbee, A Study of History, Vol. II (2nd ed.; London: Oxford University Press, 1961), pp. 527-8.

4. Edward Horton, The Age of the Airship (Chicago: Henry Regnery Co., 1973), p. 34.

5. S. Colum Gilfillan, The Sociology of Invention (Cambridge, Mass.: M. I. T. Press, 1970), pp. 6, 131.

6. Toynbee, A Study of History, Vol. VIII (London: Oxford University Press, 1939), p. 215.

7. Herbert J. Muller, The Children of Frankenstein: A Primer on Modern Technology and Human Values (Bloomington, Ind.: Indiana University Press, 1970), p. 45.

8. Matthew Melko, "The Interaction of Civilizations: An Essay," Journal of World History, Vol. XI, No. 4 (1969), p. 565.

9. Toynbee, Study, V (1961), pp. 139-98.

10. Melko, "Interaction," p. 561.

11. Toynbee, Study, IV (1961), pp. 137-98.

12. Gilfillan, Sociology, p. 6.

CHAPTER II

THE LAUNCHING OF THE AERIAL AGE

The idea of being able to soar through the air has always occupied the imagination of man. So far as we know, the sky has held a position of prime importance in all civilizations. From it came both the sunshine and the rain necessary for the cultivation of the crops that supplied the basis for civilization itself. For many societies the sky (or the top of a mountain just underneath the sky) was the traditional abode of some of the most important gods whose influence was felt in the everyday life of the people. Usually, whenever the gods appeared, they came from the heavens and were observed (when they departed) to return there to resume their watchfulness over the affairs of the mortals bound to the surface of the earth. Consequently, there was a close connection in the mind of man between the ability to fly and the possession of other powers normally attributed to the gods, such as immortality and invincibility.

Little wonder that most of the schemes proposed through the ages to get man into the air had as their aim political

or military power. From Greek mythology comes the tale of Daedalus, who supposedly constructed wings for his son and himself to escape from an island ruled by a tyrant; only the hubris of his son, who aspired to imitate the gods, prevented his plan from working to perfection.

Roger Bacon (1214-92), a Franciscan monk, speculated on the possibility of flight in his work De mirabili potestae artis et naturae written about 1250 (although not published until almost three centuries later). In it are to be found references to hollow copper spheres filled with a light gas ("aetherial air") that would float in air, as well as to a device that would enable a man to propel himself above the ground by turning a crank.[1]

By the latter part of the 13th century Europeans had acquired knowledge of the kite, either discovering it for themselves or learning of it from the Chinese, to whom it might have been known for many centuries.[2] These kites were of two basic types: (a) the familiar plane-surface kite usually in the shape of a diamond or pentagon and (b) the wind-sock kite usually adorned with fins and decorations to resemble a dragon. It is possible that the Chinese placed small oil lamps in the open ends of some of these dragon kites, and that air warmed by the flames actually made them tethered balloons. Their aeronautical discoveries were virtually useless to the Chinese who, as

Needham has pointed out, had little need of many of their technological insights.[3]

Another approach to unraveling the mystery of flight was taken by that creative genius Leonardo da Vinci (1452-1519). Among the military engineering plans and sketches of paintings in his notebooks are some designs for flying machines capable of carrying men aloft. Like the plane-surface kites, his devices depended upon aerodynamic principles for their lifting capabilities: that is, they flew by exerting pressure against the resistance of the air rather than being buoyed to a point of equilibrium with the surrounding atmosphere (aerostatic principle). Evangelista Torricelli scientifically demonstrated the latter principle with the barometer he constructed in 1643. Within three decades, Fra Francesco de Lana, a 17th century Jesuit priest, proposed a platform suspended from four or more balloon-like copper spheres from which the air had been removed, thus enabling it to float. While professing abhorrence of the idea, the good cleric suggested that this device would enable its user to overcome the defenses of fortified cities and bombard their inhabitants into submission.[4]

At the court of the king of Portugal in 1709 Father Bartolomeo Lourenço de Gusmão (1685-1724) inflated a ball with hot air and let it float to the ceiling. He made an unsuccessful appeal to the Crown for a grant to build an

airship of his design that would operate on the demonstrated principle.[5] Its most unique feature was a large magnetically operated bellows meant to propel the craft by blowing air into a sail spread above the gondola.

However, it was not until near the end of the 18th century that man annulled the hitherto apparently unbreakable bond that chained him to the earth. Experiments to escape the previously immutable pull of the force of gravity were begun in the latter part of 1782 by two French brothers, Joseph M. (1740-1810) and Jacques E. (1745-99) Montgolfier. Having observed that smoke (hot air) tended to rise, they constructed a small oblong paper bag that floated to the ceiling of their apartment when it was filled with the gases rising from an open hearth.[6] They then built several larger balloons. On September 12, 1783, Jacques Montgolfier demonstrated their discovery before the members of the Royal Academy of Sciences in Paris.

This flight and the one which followed (as a demonstration for the Monarch and his family) were unmanned; although the second trial carried a sheep, a rooster, and a duck, all of which were found to be unharmed when the aerial vehicle returned to earth. On October 15, 1783, Pilatre de Rozier (1756-86), an associate of the Montgolfiers who had established a reputation for performing hazardous feats, made a trial flight in a tethered balloon. On November 21, accompanied by François-Laurent d'Arlandes,

who had interceded with the King to obtain permission for the flight, de Rozier made the first recorded aerial voyage.[7]

Despite the relative success of the manned ascensions in the Montgolfier balloons, both the participants and the spectators of these and later flights regarded the hot-air, coal-gas, or hydrogen balloon (developed by Professor Jacques Charles, a close rival of the Montgolfiers) as a scientific curiosity or carnival attraction. It was all but useless as a form of transportation. There was, in fact, little the pilot could do to control his direction of flight once he entrusted his craft and himself to the winds. His ability to make a safe return to earth depended very largely on chance.

Yet, experiments in air flight never ceased. Indeed, the onset of modern war in the 18th century increased them. Hard-pressed to find ways of defeating the armies of the first coalition, and perhaps influenced by Benjamin Franklin (who had observed one of the Montgolfiers' flights) and André Giraud de Villette (who had ascended with de Rozier), the French republican government legislated the first military aerial observation unit into existence on April 2, 1794. Captain Jean Marie-Joseph Coutelle accepted command of the Compagnie D'Aerostiers. After being rapidly transported to the front, the unit had but a few opportunities to perfect its technique before it was called upon to

provide reconnaissance for the engagement with the Austrians that became known as the Battle of Fleurus. Its balloon, the Entreprenant, remained aloft some nine hours with the observers aboard transmitting valuable information about enemy intentions and troop movements.[8]

The exploits of Coutelle's Compagnie D'Aerostiers notwithstanding, the large unwieldy gas generator and the bulky raw materials needed to supply it prevented the acceptance of the hydrogen balloon as an adjunct to the more conventional reconnaissance methods. Not until the American Civil War did balloonists such as Thaddeus Lowe demonstrate the real practicality of the balloon as an observation platform. From shortly after the outbreak of the war in 1861, Lowe and other "aeronauts" (as they styled themselves), convinced that aerial observation would give Federal armies a tremendous advantage (as well as bringing themselves everlasting fame), strove to establish a balloon corps.[9] Despite the difficulties inherent in transporting and inflating the clumsy balloons, Lowe secured an appointment as a balloonist to the Army of the Potomac; the others pursued their interests as "aeronauts" under the patronage of various field commanders.[10]

Until 1863 (when Lowe resigned in protest), the commanders of the Army of the Potomac received valuable intelligence telegraphed from Lowe's balloons. In addition, the appearances of these craft hovering above

the Federal positions evoked unease among the Confederate generals.[11] Failing to destroy the Union balloons by artillery fire, the Confederates began to construct balloons themselves. The first of these was inflated and launched at Yorktown, Virginia, in 1862. Being made of cotton rather than silk, it was too heavy and too poorly insulated to get far off the ground; still, its single scared passenger (a reluctant Confederate "volunteer") was able to send valuable information to those on the ground by using a wig-wag signal.[12]

Some mystery surrounds the second Confederate aerostat, known as the "silk dress balloon." A perhaps apocryphal story attributed to Confederate General James Longstreet relates that the Southern military, having no silk (a scarce item in the South) for a balloon, launched a patriotic drive to secure enough silk dresses to enable Captain Langdon Cheves of Savannah to construct one. Whether this actually occurred is doubtful.[13] The multi-colored appearance of the balloon (which may have been the origin of the "silk dress" story) probably resulted from Cheves having to use strips of silk that were neither the same color nor pattern.

Whatever its origin, the balloon was brought to Richmond where it was inflated in June, 1862, and towed to the front lines. Once in the possession of Lee's Army of Northern Virginia, it was taken up daily to observe the

movements of the Union forces. In the latter part of June, when the Federals reached Malvern Hill, the Confederates began sending their aerostat down the James River on an armed tugboat, the C.S.S. Teaser. They made several ascents from the deck of this craft before it ran aground and a Federal gunboat, the U.S.S. Maritanza, put an end to the operation by capturing both balloon and boat.[14] Thus ended Confederate ballooning.

Despite their seeming technical advantages and better fortunes, the Federals were also compelled to abandon the use of balloons. There were few civilian aeronauts (ballooning was considered strictly a civilian occupation and the Army would have nothing to do with it), and the pay of six dollars a day provided little incentive to risk one's life in the flimsy contraption which, when free to float, was at the mercy of the winds and might fall into enemy hands, and, when tethered, was an easy target for improved artillery and rifle fire. Yet the value of these balloons was summed up by Confederate General E. Porter Alexander when he wrote:

> We could never build another balloon (after the loss of Dr. Cheves' creation on the James), but my experience with this gave me a high idea of the possible efficiency of balloons in active campaigns. Especially did we find, too, that the balloons of the enemy forced upon us constant troublesome precautions in efforts to conceal our marches.[15]

The use of tethered balloons as aerial observation posts in the American Civil War was brief, with only

intermittent and qualified success. For some time yet the dream of controlled flight was to remain unfulfilled. Even when the force of gravity had been overcome (as it was during the Civil War), the problems of direction and speed control remained.

Joseph Montgolfier had expressed his ideas on the problem of steering a balloon in October, 1783:

> To find a force with which we could keep the craft aloft, we turned to fire. The first idea that came to us was the force of reaction, something which can be harnessed without machinery or expense. All it requires is that one or more openings be made in the craft on the side opposite the direction in which you wish to move. When the gas escapes through these openings, this part of the fabric ceases to be inflated and so the balance of the inside area is altered . . . .[16]

Other pioneers conducted experiments with paddles, oars, sails, and still other contrivances rigged to provide sufficient "reaction" to propel and steer the aircraft. All proved to be impracticable methods of control. Attention then shifted to the idea of taking aloft some sort of power unit that could provide controllable motion even against the wind. To keep weight to the absolute minimum many experimenters concentrated on developing a system of propulsion utilizing the muscles of the human body through some peddle or cranking arrangement. Others, realizing that human power was insufficient, tried to solve this problem by the use of machines.

The pioneer in these developments was Sir George Cayley (1773-1857). Known for his work in aerodynamics, Cayley was one of the first to appreciate that balloon navigability depended upon the development of an engine with a considerably higher power to weight ratio than was then available. Aware that clumsy reciprocating steam engines required considerable modification for this purpose, from 1805 to 1808 he experimented with a hot-air engine as well as one utilizing a gunpowder-driven piston in anticipation of the internal combustion engine.[17] In 1816, he returned to the steam engine and incorporated it as the propulsive unit in a design for a dirigible with separate gas compartments in a rigid frame. The steam engine being the marvel of the 19th century, as well as the principal form of mechanized motive power, it was perhaps only natural that Cayley and others should have thought of it as a means of propelling a balloon.

Securing an efficient method of propulsion was, however, only one of the problems confronting early flight. Not least important was how to make the balloon dirigible. The spherical or pear-shaped envelope of the free balloon achieves and retains its shape because of equal pressure from all sides; yet once the attempt to move the balloon against or across the wind is made, it becomes a source of resistance. A number of solutions were forthcoming, but eventually most adopted the idea that the bag should be

elongated into an ellipsoid, cylindrical, or cigar shape having its major axis parallel (generally) to the ground; lines attached to both ends of the envelope provided the necessary triangulated rigidity between the balloon and the power car.

This stretching of the envelope destroyed the inherent stability of the round balloon by introducing complicating but necessary factors such as weight distribution and maintenance of the original shape of the gasbag. If the weight carried aloft was concentrated in one position, then unequal stresses would be applied to the lines with the result that the envelope would either stand on end or fold in the center. If loss of gas were to cause the balloon to sag or crumple, the result would be the same.

One solution to a crumpling gasbag was proposed in 1783 by Jean Baptiste Marie Meusnier (1754-93), an officer in the French army. His device, known as a ballonet, is a small balloon located inside the larger gasbag that could be filled with air by a pump or compressor; when the gas contracted or leaked out, inflating the ballonet provided compensation. Equipped with a safety valve, it could also be used to keep the balloon from bursting, or reduce the loss of gas resulting from a fall in external pressure.[18] Meusnier's invention was incorporated into the first elongated balloon to fly (in 1784). This was built by the Montgolfiers' hydrogen balloon-advocating rival,

Jacques A. C. Charles (1746-1823) and his associates (the brothers Ainé and Cadet Robert) under the direction of the Duc de Chartres. Because the ballonet was placed in a position that prevented the valving of gas at altitude, the flight almost ended in disaster. On a second attempt the brothers Robert built a cylindrical balloon that proved no more dirigible than its predecessor; nevertheless, primarily because the ballonet kept the loss of hydrogen to a minimum, on September 19, 1784, Cadet was able to fly from Paris to Béthune, where he landed in the midst of a fête being given by the Prince de Ghistelles for the workers on his estate.[19] The distance covered (approximately 150 miles) in the few hours of the flight was unprecedented. Within a year of its discovery the hydrogen balloon was providing substantial periods of flying time. Almost all serious experiments concentrated on its use to the detriment of its hot-air rival, which was increasingly relegated to the role of a sporting device.

As might be expected, for most of the 19th century Europe remained the center of experiment and development of controlled flight. Important was the contribution of Henri Giffard (1825-82), a French mechanic who specialized in the construction and improvement of light, comparatively efficient steam engines. Having seen a model airship being demonstrated at the Paris Hippodrome in 1850 he became convinced that he could adapt one of his steam engines to serve

as a power unit. In 1852, his work in steam units culminated in the building of a five horsepower engine that weighed approximately 100 pounds. After persuading two of his friends to provide sufficient funds for the venture, Giffard designed an elongated aerostat around his engine.

The balloon he built had a football-shaped gasbag 144 feet long. A net covering this envelope supported a pole 66 feet long from which was suspended the gondola that housed the engine and its operator. On September 23, 1852, Giffard launched his airship, which actually made headway off the ground. However, the relatively small size of the gasbag and the weight of the load prevented the aerostat from gaining much altitude. Moreover, the three-bladed 11-foot diameter propeller was capable of driving the craft forward at a speed only slightly in excess of six miles per hour.[20]

Encouraged, rather than daunted, by the results of this experiment, Giffard proceeded to build yet another balloon. The gasbag of his second aircraft had a shape more like a cigar, being some 230 feet long and 33 feet across at its widest point amidships. With this exception, the second aerostat was practically the same as the first. Giffard mounted the same engine in it and, as before, took the same essential precautionary measures of extending the boiler smokestack far to the rear and covering the stokehole

with a wire mesh to prevent an accidental spark from igniting the hydrogen.

This balloon made only one trial flight, during which Giffard was able to move steadily against the wind. The attempt to descend, however, caused the power car to tip forward and put too much strain on the supporting net which caused the car to plummet to the ground. Although neither Giffard nor anyone else was injured in the accident, the experience discouraged potential investors. Unable to raise the necessary funds for his third dirigible (which was intended to be almost ten times the length of the previous one) Giffard postponed the project until the onset of blindness caused him to give up the idea altogether. His engine had proved too heavy: it could not provide enough power to drive the combined mass of the balloon and itself through the air against even light breezes.

In their efforts to overcome this problem, other European experimenters seized upon new methods of power generation. One of the principal forerunners of the internal combustion engine had been patented in 1860. Twelve years later an Austrian by the name of Paul Haenlein (1835-1905) used it to propel a dirigible.

The envelope for Haenlein's airship had the shape of the hulls of two ships, one inverted over the other, measuring 164 feet in length with a maximum diameter of 30 feet. The power car was suspended just a few feet

beneath the balloon. His plan was to fill the gasbag with coal-gas instead of hydrogen and draw upon this to fuel the engine at the rate of 250 cubic feet per hour. As the capacity of the balloon was some 85,000 cubic feet and the lifting capability of coal-gas was far lower than that of hydrogen, Haenlein's aerostat suffered from a lack of lift that could only get worse as the flight progressed. Nevertheless, tethered test flights were carried out on December 12 and 13, 1872, at Brunn, Moravia, during which the airship attained a speed of above nine miles per hour. Disappointed and unable to raise funds to carry on, Haenlein ceased his experiments.

Almost a decade later, in 1881, one of Giffard's countrymen, Gaston Tissandier (1843-99), took up the idea of a mechanically powered aerostat. Like Giffard, his desire to experiment with balloons stemmed from a general interest in the source of motive power; like Haenlein, his power plant was one previously untried: in this instance, an electric motor.[22]

In Gaston Tissandier's view, the electric motor would provide the ideal power plant for an airship. Having neither flame nor exhaust, it greatly reduced the possibility of accidental ignition of the hydrogen in the gasbag. It also avoided another drawback of the steam engine. Whereas an airship propelled by steam was lighter at the

end of the journey (insofar as fuel was consumed) than at its beginning, one utilizing electric batteries had no significant variance in weight.

In order to demonstrate the plausibility of his ideas, Tissandier constructed a miniature airship powered by a small electric motor and batteries, which he exhibited at the Parisian Electrical Exposition of 1881. During its indoor trial flights the little airship was able to move in a predetermined direction at somewhat over five miles per hour.[23]

Confirmed in his belief, Tissandier began looking for financial assistance to produce a larger model capable of carrying a man aloft. Unable to convey his enthusiasm to any of the capitalists whom he approached, he eventually obtained funds from his brother Albert (1839-96).

Realizing the need to reduce weight, Gaston designed not only his own more efficient and lighter potassium bichromate batteries but also a one-and-a-half horsepower motor, which was geared to a twin-bladed propeller at a ratio of ten to one. Meanwhile, his brother Albert, now having become enthralled with the whole idea, supervised the assemblage of the gasbag.

Their craft was launched on October 8, 1883. After a successful flight, they landed in a field and anchored their airship, planning to ascend again in the morning.

However, during the night, the battery solution crystallized, forcing the brothers to abandon the whole idea.[24] With insufficient funds to continue, the Tissandiers withdrew from further experiments in air flight.

The next great stimulus to the development of the powered balloon was provided by the siege of Paris during the latter stages of the Franco-Prussian War (1870-1). Having no other means of communication with the rest of the unoccupied country, the besieged Parisians resorted to building and sending out unpowered balloons that carried trained carrier pigeons, correspondence, and politically important passengers (among others, Leon Gambetta, who organized resistance to the invading Germans in the provinces and later became a central figure in the Third Republic). In all, some 64 balloons were released during favorable wind conditions; of these, only eight were lost, two to the Prussian Army and six to the sea.

The success of this endeavor aroused the interest of military men in both France and the newly formed German Reich. The army balloon corps of each nation helped disseminate knowledge about experiments with airships, which they supported sometimes to the extent of underwriting the whole project, as the French military did during the Franco-Prussian War and in 1884-5.

In the former instance, Dupuy de Lôme (1816-85), the marine engineer commissioned to design and build the craft,

incorporated the ballonet advocated by Meusnier in the late 18th century into a large egg-shaped main gas envelope. On February 2, 1872, his airship was given its only test flight. A crew of eight men cranked a shaft connected to a large four-bladed propeller. Despite their utmost exertions, they could coax only a few miles per hour from their massive, awkward craft. De Lôme's usage of human muscle for propulsive power restricted his vessel's greatest speed severely; in fact, it moved no more rapidly than Giffard's balloon had 20 years earlier.[25]

As for the second experiment, in 1884, two French army captains (Charles Renard [1847-1905] and Arthur C. Krebs [b. 1850]) secured the financial backing of the French balloon corps and, building upon the experience of de Lôme, took up where the Tissandier brothers had left off. According to Renard, he and Krebs had initially set forth certain prerequisites for their airship: horizontal and vertical aerodynamic stability, minimization of forward resistance, and ability to move against the wind.[26] In the event, the craft that emerged from their plans embodied several innovations. Unlike those of the Tissandiers and de Lôme, the gas envelope was streamlined to a near point at either end, as was the bamboo and silk car suspended beneath. The batteries, motor, and propeller occupied the forward section of this gondola; at the rear was a large rectangular rudder; the instruments were located in the

central section where the pilots sat. In addition to controlling the motor and rudder, the aeronauts could also slide a weight toward either end of the airship to maintain horizontal equilibrium and lower a heavy rope, known as a trail-rope, to reduce the risk of violent landing.

Duly christened La France, the airship was launched on August 9, 1884, with Renard and Krebs at the helm. They managed to steer their aerostat and bring it back to the point of departure under its own power, having covered about five miles in a little under 30 minutes.[27] Although they flew their airship several more times, they were compelled to conclude that the maximum possible speed of the craft--about 14 miles per hour--was quite insufficient to be practical. Yet, they had demonstrated the possibility of real aerial navigation.

Meanwhile, the German Army, after a false start with two hastily improvised balloon companies at the siege of Strasbourg in 1870, had its interest sufficiently aroused by news from France, and lighter-than-air advocates at home, to establish its counterpart to the French balloon corps in 1871.[28] In 1897 the Prussian Airship Battalion succeeded in completing the construction of an airship of a new type. This vessel had a rigid aluminum gas envelope consisting of .008 inch aluminum sheeting over a tubular framework of the same metal; some 156 feet long and of an

elliptical cross-section (being 46 feet in height and 39 feet in width), the bag had a conical nose and a rounded, somewhat concave stern.[29] Its capacity was approximately 130,000 cubic feet. The originator of this design was the Austrian engineer David Schwarz (1856-97) who was working at this time in Berlin.

The gondola suspended beneath Schwarz's aluminum gasbag was connected to it by aluminum girders. The two-cylinder gasoline engine (also made of aluminum) transmitted its twelve horsepower output via a belt system to two tractor propellers mounted abreast on either side of the gasbag at the bow of the car and a third propeller above the stern of the car that was movable upon its axis for control purposes. The importance of Schwarz's innovation is that it utilized the principle of rigid construction throughout.

Schwarz, however, having died early in 1897 before finishing his creation, the German military decided to carry the work through to completion. In November, after the final checks were made, and the problem of filling the rigid envelope was solved by using an extra interior air-filled linen bag that was withdrawn as gas was pumped into the shell, a young officer by the name of Ernst Jagels volunteered to ascend by himself from the Tempelhof Field in Berlin.[30]

Upon reaching a height of 800 feet, he turned the airship into the wind and started trying to make headway.

But the vessel could not move forward against the 15 mile-per-hour wind, and the engine stopped after the belts slipped from their pulleys. With his fragile craft drifting before the wind, the amateur pilot hastily valved off a large quantity of gas, causing the airship to descend rapidly. The resulting impact smashed part of the aluminum; before anyone could help, the wind had completely wrecked the crippled ship.

It was at this time that the man whose name was to become synonomous with the rigid airship--Graf Ferdinand von Zeppelin (1838-1917)--began to make his influence felt. A distinguished retired general of cavalry, he had witnessed Jagels' fall at the Templehof Field. He had, in fact, been interested in air flight for more than a generation. In 1863, while serving as an observer of the American Civil War for the King of Württemberg, he had ascended in a balloon at Fort Snelling near St. Paul, Minnesota.[31]

A decade later, during the siege of Paris, Zeppelin's position in the German General Staff Headquarters at Villiers near Paris had also enabled him to observe the flights of the balloons from the besieged city. The importance of the effects of the flight that carried Gambetta out of Paris to

organize armies in the provinces was not lost upon him. Zeppelin himself, however, gave credit for the impetus to draw up the first plans for a rigid dirigible to an 1874 pamphlet by Heinrich von Stephan (1831-97) the German Minister of Posts. It was Stephan's allusion to the fact that the vast ocean of navigable air surrounding the earth lay wasted and empty that caused Zeppelin to turn his thoughts to air transportation.[32]

Regardless of the catalytic agent, the predominantly military attitude of his mind and approach to his ideas--so far as airships were concerned--are revealed in a routine report he wrote in 1887 as the military attaché in Berlin of the King of Württemberg:

> If airships are to be of any real use for military purposes, it is imperative that these airships shall be able to navigate against very strong winds; they must be able to remain in the air without landing for at least twenty-four hours, so that they can perform really long reconnaissance operations. These airships must have a sizeable capacity for personnel, supplies, and ammunition. These three demands would require extensive balloon compartments for the necessary gas. In other words: large airships will be needed.
>
> Following are the main factors in the development of dirigible airships: the shape of the airship best suited to cut through the air must be determined; a way must be found of rising in the air without being forced to throw off ballast; a way must, likewise, be discovered of descending without being forced to valve off (and thus waste) quantities of gas. If it is possible to solve these problems successfully, the importance of airships in the future will certainly be immeasurable. Not only will they be important in warfare; they will be used for civil transportation (airships would represent the shortest

> journey across mountains, across the sea, or between any two places); moreover, they will also be used on expeditions of discovery (to the North Pole, to Central Africa).[33]

After the Count's forced retirement from the army following the spring exercises in 1890 (alledgedly for committing the indiscretion of not letting the Kaiser's chosen units win), he devoted his full time and energy to the study of the problems involved in the construction of an airship such as he had described.[34] Needing an assistant trained in technical problems, he engaged the services of the engineer Theodor Kober. Their early experiments with various propellers were conducted in a motorboat on the Bodensee. In line with his conviction that an airship must be large to be practical, one of Zeppelin's early blueprints depicts a vessel almost 420 feet long and 38.5 feet in diameter, with a capacity of almost 400,000 cubic feet of gas. His plans also called for a special hangar to be built on the Bodensee as the Count preferred to experiment there.

At length, in 1893, after three years of patient concentrated work, plans were sufficiently complete to serve as a basis for the request for financial assistance from the German government. However, Zeppelin's presentation of his proposals at the Ministry of War were unsuccessful. Undaunted at having experienced a cool reception there, he tried other governmental departments, all to no

avail. When he realized the futility of further efforts in this direction, he immediately decided to petition the Kaiser for a hearing before a select commission of scientific experts. The report of this commission would be made available to the Ministry of War.[35] So confident was Zeppelin that he sought the appointment as chairman of the commission of a renowned opponent of the idea of dirigibles, Professor Hermann L. F. von Helmholtz (1821-94).

Alas, the report, after the commission's initial session in March, 1894, was largely negative. Yet Helmholtz admitted that Zeppelin's plan was at least possible. The Count was told to work out his design in greater detail. Before he could complete this task, Helmholtz died. The other members of the commission, after receiving and reviewing Zeppelin's additions and revisions, rejected the whole scheme as practically useless.[36]

Despite the shattering effect of this decision, Zeppelin returned to Friedrichshafen to continue his work. Two years later, in 1896, he sent an outline and explanation of his work to the Association of German Engineers, requesting them to determine what, if anything, was scientifically wrong with his ideas. Finding little to criticize, the Engineers' Association issued a favorable report to the press and called for public contributions to finance the Count's work. The following year (1897), the Engineers' Association appointed a committee of experts

to assist Zeppelin with the construction of an airship according to his design.[37]

The help Count von Zeppelin received both from the experts and the German engineers notwithstanding, the primary obstacle remained insufficient funds. All the other essential preconditions for invention--for example, need (manifested in the many attempts), knowledge of the technical aspects (the hydrogen balloon and the internal combustion engine), and public willingness to accept--were present. Never suffering from a loss of confidence in himself or his ideas, Zeppelin decided to commit his not inconsiderable personal fortune to the venture. In 1898, he formed a limited liability corporation, the Aktiengesellschaft zur Förderung der Luftschiffahrt, to construct rigid airships.[38] His decision proved to be a landmark in the history of the airship. Although his wealth was soon consumed in the venture, by one means or another he continued as director as well as principal stockholder of the corporation until the world's first rigid airships had been built.

NOTES

1. Charles H. Gibbs-Smith, ed., _Aviation: An Historical Survey from Its Origin to the End of World War II_ (London: HMSO, 1970), p. 4.

2. _Ibid._, p. 3.

3. Joseph Needham and Wang Ling, _Science and Civilization in China_, Vol. IV, part II (Cambridge: University Press, 1965), pp. 586-7, 96-8.

4. Fulgence Marion, _Les ballons et les voyages aériens_ (Paris: Hache He & Co., 1881), pp. 15-8.

5. Gibbs-Smith, _Aviation_, p. 15.

6. John Wise, "The Birth of Flight," in _Lighter-Than-Air Flight_, ed. by C. V. Glines (New York: Franklin Watts, Inc., 1965), p. 5.

7. Francois-Laurent d'Arlandes, "The First Aerial Voyage," in _Lighter-Than-Air Flight_, pp. 12-5.

8. A.Hildebrandt, _Die Luftschiffahrt nach ihrer geschichtlichen und gegenwärtigen Entwicklung_ (Munich: R. Oldenbourg, 1910), p. 88.

9. Mary Hoehling, _Thaddeus Lowe: America's One-Man Air Corps_ (Chicago: Kingston House, 1958), pp. 80-90.

10. _Ibid._, p. 90.

11. F. Stansbury Haydon, _Aeronautics in the Union and Confederate Armies, with a Survey of Military Aeronautics Prior to 1861_, Vol. I (Baltimore: Johns Hopkins Press, 1941), p. 358.

12. John Randolph Bryan, "Balloon Used for Scout Duty," _Southern Historical Society Papers_ (Richmond: 1905), pp. 33-42.

13. Letter, Cheves to Squires, as cited in J. Duane Squires, "Aeronautics in the Civil War," _American Historical Review_, Vol. XLII (1937), p. 644.

14. E. Porter Alexander, Military Memoirs of a Confederate (Bloomington, Ind.: Indiana University Press, 1962), p. 172.

15. Ibid., pp. 172-3.

16. Quoted in C. V. Glines, ed., Lighter-Than-Air Flight, p. 151.

17. Robert Jackson, Airships (Garden City, N.Y.: Doubleday & Co., 1973), pp. 24-6.

18. L. T. C. Rolt, The Aeronauts, A History of Ballooning, 1783-1903 (New York: Walker & Co., 1966), pp. 204-5.

19. Ibid., p. 58.

20. C. J. Hylander, "Steam, Electric, and Man-Powered Dirigibles," in Lighter-Than-Air Flight, p. 154.

21. Rolt, The Aeronauts, pp. 212-3.

22. Jackson, Airships, p. 35.

23. Hylander, "Steam . . . Dirigibles," in Lighter-Than-Air Flight, p. 156.

24. Ibid., pp. 156-7

25. Rolt, The Aeronauts, p. 211.

26. Charles Renard, "Success at Last!" in Lighter-Than-Air Flight, pp. 158-9.

27. Ibid.

28. John Fisher, Airlift 1870: The Balloon and Pigeon Post in the Siege of Paris (London: Max Parrish, 1965), p. 15.

29. Carl Berg, David Schwarz, Carl Berg, Graf Zeppelin: Ein Beitrag zur Entstehung der Zeppelin-Luftschiffahrt in Deutschland (Munich: By the Author, 1925), pp. 8-9.

30. Ibid., p. 11.

31. Margaret Goldsmith, Zeppelin: A Biography (New York: William Morrow & Co., 1931), p. 45.

32. Hugo Eckener, Graf Zeppelin (Stuttgart: J. G. Cott'sche Buchhandlung Nachfolger, 1938), p. 104.

33. Luftschiffbau Zeppelin, _Das Werk Zeppelins, Eine Festgabe zu seinem 75. Geburtstag_ (Stuttgart: Kommissionsverlag Julius Hoffman, 1913), p. 1.

34. Eckener, _Graf_, pp. 102-3.

35. Germany, Militärgeschichtlichen Forschungsamt, _Die deutschen Luftstreitkräfte von ihrer Entstehung bis zum Ende des Weltkrieges 1918, Die Militärluftfahrt bis zum Beginn des Weltkrieges 1914, Anlageband_, Letter, "Generalleutnant z. D. Graf von Zeppelin an den Chef des Generalstabes der Armee," September 14, 1893 (Freiburg im Breisgau: E. S. Mittler, 1965), document #11, pp. 13-4.

36. Germany, Militärgeschichtlichen Forschungsamt, _Die deutschen Luftstreitkräfte_, "Kommissionsbericht über die Prüfung neuer Entwürfe des Grafen Zeppelins," March 2, 1895, document #17, pp. 24-6.

37. Eckener, _Graf_, pp. 137-8.

38. _Ibid._, p. 140.

CHAPTER III

FROM THEORETICAL IDEAS TO PRACTICAL APPLICATION--- THE PROBLEM OF FINANCIAL BACKING

One of the greatest difficulties facing those who wished to develop the dirigible was the reluctance of the private and public investor to invest in the industry. Inventors like Giffard (who realized that an airship must be large to accommodate the propulsion unit and a practical payload) found it impossible to convince private capitalists or the government that the industry offered profitable and important prospects. This may, in part, be attributed to the lack of business sense shown by some of the early experimenters. Gaston Tissandier, for example, found it difficult to sell his ideas even to his own brother Albert. Yet Giffard was a successful engineer and inventor of some means with friends in commerce and government. Renard and Krebs (whose airship was built at a French military balloon factory at Chalais-Meudon with money supplied by the Third Republic) seemed to have been able to sell their ideas to members of the French government; likewise Schwarz (whose aluminum dirigible was completed under the aegis of the Prussian Airship Battalion after his death). Obviously

the money was available--if those responsible for its distribution could be convinced of the practicality of the airship. Giffard's failure to raise funds can, of course, be put down to the crash of his second airship in 1855. Similarly, the experiments of Renard and Krebs were discontinued when it became evident that La France was navigable only in the lightest breezes. Schwarz's airship had numerous mechanical deficiencies besides its slipping drive belts.[1] Technologically, the airships built by these men had no practical value; their inventors had created curiosities rather than inventions needing only financial support. What they had invented were test models intended to bring fame and perhaps fortune, rather than something able to carry a payload from one place to another. Their work had serious design, structural and operational shortcomings; and those that served as the basis for proposals for further development gave little promise that anything significant would come of them.

Perhaps Count von Zeppelin was the exception; practical utility was the foundation of his concept. The descriptions and sketches of his earliest known mental image of the rigid airship are drawn from entries in his diaries made while he was recuperating from a riding accident about two months after reading Heinrich von Stephan's pamphlet (1874). Beginning on March 25, 1874, the entries

depict a dirigible of monstrous proportions (in comparison to its contemporaries) with 18 gas cells having a total capacity in excess of 706,000 cubic feet (over eight times as much as La France 10 years later). The hull consisted of rings and longitudinal braces with an overall fabric cover as in his later airships. Slung beneath this structure were cabins for 20 passengers, and holds for cargo and mail.[2] A rather curious feature was the envisioned use of adjustable inclined planes to provide aerodynamic lift: the forward motion of the airship would cause these planes to push the vessel upward until the desired altitude was attained. Then either the inclination of the planes or the speed would be reduced, permitting the craft to kite until descent became desirable, at which time the planes could be put in a horizontal position and the speed throttled.[3] Although abandoned by the Count shortly thereafter, this idea was actually put into practice later when airship commanders wanted to take off with their vessels having negative buoyancy (i.e., when the airship was too heavily loaded to float).[4]

The practical difficulty of gas loss also drew Zeppelin's early attention. It appears that he was well aware of the relatively high degree of permeability of the balloon fabric then in use, as well as the necessity to replenish that gas which was lost when it became imperative to valve off at high altitudes on extended trips. His solution was

to provide the airship with some form of gas generating equipment on board--an altogether wasteful scheme that was dropped because the gas generator and its raw materials would weigh more than the amount of hydrogen it produced could lift.[5]

Committing some speculative ideas on airships to a diary was one thing; building and flying an airship was another. In any event, there were too few private sources of capital in 19th century Germany willing to back a pioneering undertaking. Consequently, most German inventors (where they could) sought government financial assistance; Count von Zeppelin was no exception. Indeed, as an old military officer, he thought in national terms. He was obsessed with the idea of providing rigid airships not for private gain, but for the German Reich. First, however, he had to convince the government of the practicality of his airship.

To this end, in 1891 he presented the Prussian War Ministry with a design derived from basic ideas along the lines set forth in his diary. Outlining his proposals in a letter to Alfred von Schlieffen (Chief of the General Staff), he requested that a technical officer be sent to consult with him regarding his ideas.[6] Schlieffen sent Captain von Tschudi, the commander of the Prussian Airship Battalion, to Stuttgart where at that time Zeppelin was developing his airship ideas. Although no report exists in

Tschudi's name, Zeppelin wrote that the Captain had encouraged him to proceed with his plans and experiments.[7] The general description in Zeppelin's patent specification of August 31, 1895, is the one definite piece of information that we have to go on as to what Zeppelin intended.[8] The "Deutschland" design, laid down in the patent, had three sections connected with an elastic coupling. The forward, powered section was approximately 385 feet long, including a domed bow with a radius of 18 feet. The central segment was 52.5 feet in length, and the rear unit was 113 feet long plus another 18 feet of hemispherical stern. The rings (36 feet in diameter) of each section were circles of hollow aluminum tubing with a cross-section of somewhat less than six inches. Four cylindrical beams of the same material located at the top, bottom, and center of both sides provided the only longitudinal stiffening: the other longitudinal members were wires. There being somewhat over 26 feet between the rings, the longitudinals could produce little effective resistance to compression or bending forces, even when combined with wire netting in strategic locations. A perpendicular brace on each ring formed, in combination with the top and bottom longitudinal cylinders and diagonal wire bracing between rings (through the gas cells), a braced structure capable of withstanding significant loads in the vertical plane. The material of the gas cells was unspecified, but the outer covering was to be of

silk fabric or "similar material." Each gas cell was equipped with both manual (at the top) and automatic (at the bottom) valves for the release of hydrogen. Suspended beneath the hull and attached rigidly to it were several open cars, and the two of these beneath the forward section each held a Daimler 11 horsepower engine weighing over half a ton. Each engine drove two small four-bladed propellers located high on the side of the hull. Connecting these cars with the others was a narrow walkway suspended on wires. Control in the vertical plane was to be effected by sliding back and forth a heavy weight suspended beneath, while a comparatively tiny pair of rudders at the bow were to give the pilot directional control.

When Zeppelin submitted this design to the Helmholtz Commission (p. 46 above) for examination, he suffered a setback in his quest for government support. The Commission rejected the Count's scheme out of hand largely as a result of the calculations of Professor Heinrich Müller-Breslau (1851-1925) of the Technical College at Charlottenburg, whose background in bridge design made him an authority in stress analysis. He wrote:

> It fell to me to test the rigidity of the body of the airship. The result of my calculations were most unfavorable. The static calculations of the engineer entrusted with the working out of the details of the design were confined to the investigation of a vertical framework which passed through the airship, dividing it into two halves . . . Nothing whatever had been done

> in the way of providing for horizontal rigidity of the airship, or for torsional moments . . . . This ship, the rigidity of which was in a high degree dependent upon the pressure of the gas, was to be anchored on the ground in the open. No hangers were provided for.
>
> It was of course possible to strengthen the framework, but owing to the very small useful life--it was only 880 pounds--it could be done only at the expense of the engines, which were already too weak.[9]

With Zeppelin's plans so condemned, the Commission had little choice but to reject them. The Count's reaction was a multi-page rebuttal that he sent Bronsart von Schellendorf, the War Minister, on October 21, 1894.[10] This document further strained his relations with officers in the War Ministry. Nevertheless, through the influence of his good friend, King Wilhelm of Württemberg, Zeppelin obtained a reconstituted Commission.

In the hastily redrawn design a domed stern was added, the vertical struts strengthened, and a braced framework truss 18 feet wide attached to the top of the airship; all this in an effort to circumvent Müller-Breslau's objections.[11]

However, in solving some of his problems Zeppelin only created others. As revised, the airship had a stronger but a heavier supporting structure. In an effort to improve lifting capability, the Count had substituted smaller nine horsepower engines as a weight-saving measure. Basing his calculations on a simple but erroneous formula involving

the pounds of thrust of the engines and the cross-sectional area of the envelope, he expected his ship to attain a speed of 19 miles per hour. This the Commission rejected on the grounds that air resistance had been underestimated and the efficiency of the engines and propellers over-estimated. Convinced that an airship must have at least a speed of 28 miles per hour to be of any practical value, the Commission once again ruled against Zeppelin.[12]

More than ever the Count was convinced that not until he had built and flown an airship would he be likely to obtain the government's backing. Only this could reverse the adverse publicity generated by the Commission's reports. Meanwhile, in 1896, he sent a complete copy of his latest design to the Association of German Engineers for their examination. While the friendly report they issued undid some of the criticism expressed in the Commission's findings it brought little money with which to launch a corporate enterprise. Indeed, the capitalization of the firm (the Aktiengesellschaft zur Förderung der Luftschiffahrt) founded by Zeppelin in 1898--800,000 M.--was provided primarily out of his own pocket. Thus ended for Zeppelin an eight-year period of designing airships that never flew and seeking money that was never forthcoming.

The new corporation began its activity with the building of a floating hangar near Manzell on the Bodensee.

It was Zeppelin's contention that an airship could "land" more easily on the water and that a floating hangar anchored at one end would swing with the breeze and always permit entry and departure.[13] On June 17, 1898, construction of LZ 1 (Luftschiff Zeppelin 1) began with the arrival of the first aluminum parts.[14]

The cylindrical hull of this pioneering airship was 420 feet in length and 38.5 feet in diameter with symmetrical tapering ends. However, the 24 longitudinal beams connecting the 16 transverse rings were seriously defective in design.[15] They presented next to nothing in the way of resistance to lateral or bending forces. Photographs (see next page) of the LZ 1 with its outer skin removed illustrate this problem. The rings actually were polygons with 24 sides braced with radial and chord wires. Except above the two gondolas, the rings were spaced 26.2 feet apart; above the gondolas they were 13.1 feet apart. Attached to the longitudinals were the 17 aluminum-bronze alloy gas bag nets; inside each of these was a gas cell made of light-weight cotton covered with a layer of rubber made by the Ballonfabrik August Riedinger of Augsburg.[16] Each gas cell was equipped with an automatic safety relief valve underneath; five of them had valves at the top that could be controlled by the commander in the forward gondola.

The two gondolas were held close beneath the hull by aluminum struts some 105 feet from either end. Solidly

Figure 2: Note deformation in girder running from upper center to lower right. Reprinted by permission of the University of Washington Press, from Giants in the Sky by Douglas Robinson, c 1973.

built of aluminum, these were intended to float on the water when the airship came to rest, but each also had a wheel protruding from the bottom in case the dirigible had to be brought down over land. Each car contained a 14.2 horsepower Daimler four-cylinder water-cooled engine weighing 850 pounds and its fuel. Power was transmitted to four-bladed propellers mounted on brackets high on both sides of the hull by a bevel gear and long shaft arrangement. The propellers, just under four feet in diameter, turned at 1,200 revolutions per minute. The water used in cooling the engines ran from one car to the other in tubing along a shaky ramp suspended by wires.

Besides regulating the speed of the engines and valving gas, the pilot could dump water ballast (kept in the double-bottomed gondolas and inside the hull of the ship) or winch a large weight along a line from one gondola to the other. Directional control was provided by a pair of rectangular rudders forward (above and below the bow) and another pair mounted close to the sides of the airship aft.

The completed metal frame weighed some 1,470 pounds less than the calculated weight of 10,570 pounds. With a total gas volume of 399,000 cubic feet, the airship had a lift under standard conditions of 27,400 pounds. Comparing the lift with the weight of the metal skeleton, and estimating the weight of the items yet to be added, Zeppelin hoped

for a useful lift (of cargo, passengers, and ballast) of nearly 4,200 pounds.[17] However, he had badly overestimated the lifting capacity of his ship. The engines, gondolas, gas cells and outer fabric of pegamoid (in addition to the hull frame) accounted for all but 1,430 pounds of the actual gross lift; water ballast accounted for 770 pounds more. The actual lift was considerably less than the calculated lift because of such factors as the use of impure hydrogen, and the inability to fill (or undesirability of filling) all the cells completely at lift off. Moreover, when the gas cells were inflated on a trial basis several days before the anticipated test flight date of July 1, 1900, the Riedinger cell material was found to leak badly. The purity of the ship's hydrogen could not be maintained.[18]

Nevertheless, an initial trial flight was set for June 30, and (although the Count sought no publicity) word of the impending event spread quickly through the villages and towns on the Bodensee. Spectators lined the shore and clambered aboard all manner of small craft to get a better view. Difficulties with the method of inflation arose, however, and the flight was postponed a day. The next day an equally large crowd gathered to watch. After some delay due to high wind the LZ 1 was "weighed off" and backed on its pontoon out of the floating hangar.[19] Once the airship was clear of the hangar and pointing into the wind, its engines were started. Those watching expected

it to take to the air any moment. Alas, Captain Hans Bartsch von Sigsfeld, believing that the wind was still too strong to fly an untested airship, ordered the LZ 1 back to its hangar.[20]

Late the next day the wind abated sufficiently for another attempt to be made. On this occasion, Count von Zeppelin doffed his hat, called for silence, and led all those within hearing in a short prayer. The large ship was again drawn from its hangar. The LZ 1 having cleared the shed, Zeppelin and a party of his friends climbed into the gondolas. A few minutes after 8:00 P.M., all was ready and the handling crew set the airship free from its pontoon. However, those holding the lines at the stern held on too long and the LZ 1 rose with its bow pitched at an upward angle. The sliding weight was pulled forward to correct this, but the winch operating the weight cable broke with the weight forward, making the bow heavy. Shortly thereafter, one engine died and considerable ballast had to be released from the forward gondola to prevent a headlong plunge into the lake. Despite the discharge of water, it was still necessary to stop and reverse course astern to maintain level flight. Of this, Zeppelin wrote:

> Henceforth, the whole voyage consisted of alternately going ahead, and then astern, with the screws, so as to prevent excessive inclination. A further reason for this alternate motion arose

> from the circumstance that the air ship, which at first obeyed her helm well to starboard, ran more and more to the left, owing, apparently, to a curve to larboard, due to the drag of the running weight. For this reason also, in order to avoid being driven on over the land, it was necessary to go astern with the screws whenever the stern pointed toward the lake.[21] (underscoring added)

After a quarter of an hour of maneuvering like this above the Bodensee, Zeppelin decided to land. Valving off a quantity of gas and dropping a little more ballast to partially compensate, he brought the LZ 1 back to the surface of the water 17 or 18 minutes after having left it. A line was passed to a nearby boat, which took the dirigible in tow.

Thus ended the first flight of a rigid airship. The LZ 1, the prototype of the many airships that would follow it, had flown, was controllable (although it became less so the longer the flight lasted), and had landed safely. It had thus demonstrated the possibilities inherent in a large metal-framed rigid airship.

Yet the military observers (Captain Sigsfeld as War Ministry representative and two other men from the Airship Battalion) appointed by the Kaiser had concluded that the LZ 1 was suitable neither for military nor for civilian use.[22] Although they concentrated on the low speed

(8 miles per hour maximum) and the inadequate lift of the airship (rather than its mechanical and structural weaknesses), their criticisms were generally valuable.

One of the causes of inadequate lift was the unsatisfactory gas cell material. The primary cause of most of the difficulties once the ship was airborne, however, was the longitudinal aluminum I beams. The sliding weight, added to the weight of the gondolas, caused the beams in the lower section of the ship to compress, producing Zeppelin's "curve to larboard." A picture of the <u>LZ 1</u> (see next page) shows what occurred. As the aluminum girders warped and bent, the rudders began counteracting each other, making the airship increasingly uncontrollable. It was as well that the first test flight had been made during a lull in the wind.

Undeterred, Zeppelin began correcting the defects. The I beams were not replaced as this would have entailed rebuilding the <u>LZ 1</u>--an impossible course of action as most of the initial 800,000 M. had been spent. Nevertheless, the gangway between the gondolas was stiffened and attached to the bottom of the hull by aluminum struts, thus forming the first example of what was to become accepted generally

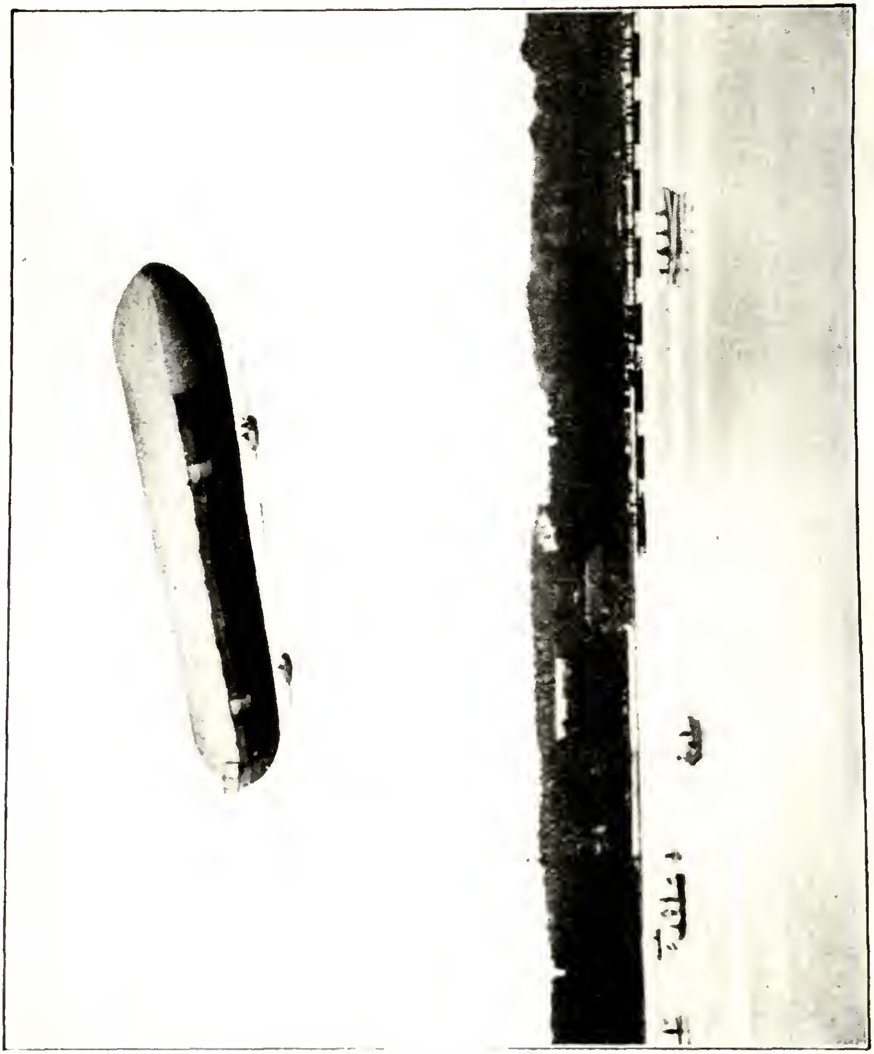

Figure 3: Note that the airship has buckled slightly amidships with the forward section sagging due to girder failure. Photograph from Luftschiffahrt by A. Hildebrandt, c 1909.

as an integral part of airship design--the keel. The sliding weight was increased by 50 per cent and brought up underneath the keel. The rudders aft were removed and placed beneath the hull; simultaneously an elevator was added below the bow. Yet, as these modifications neared completion, on September 24, 1900, some of the rings by which the uninflated airship was suspended from the ceiling broke and the central section crumbled to the floor.[23]

This unfortunate damage was repaired with almost the last of the funds available. By October 8 the LZ 1 was reinflated. Its second flight occurred nine days later, followed by a third a week after that. Because Zeppelin realized that to be forced down on land would probably be disastrous, these flights were carried out above the Bodensee. Once again, the military observers present found themselves unable to recommend the dirigible to the Minister of War. Despite the strengthened walkway, the frame was weak, and the highest estimated speed had not exceeded 17 miles per hour. In this there may have been some conflict of interest. All three observers were connected with the program of the Prussian Airship Battalion, and one of them (Major H. Von Gross) clashed with Zeppelin over the acquisition of the patents on the Schwarz airship (p. 41).[24]

This time, with funds of Zeppelin's joint stock company all but gone the Count had no choice but to dismantle the LZ 1, have the hangar brought ashore, and lay

off all his work force except an engineer and two night watchmen.[25] By March, 1901, however, he had made an appeal to the Association of German Engineers, which had supported his initial effort. This time, however, the engineers turned their backs on him. They did so because--by their view--the unsuccessful demonstration flights of the LZ 1 had ended the matter.

Rebuffed but undaunted, Zeppelin then tried to raise money by sending a stamped blank money order to each individual on an almost endless list of the "Who's Who" in the German Reich. The amount received, a mere 8,000 M., did not cover the expenses the Count had incurred in sending out the letters. Virtually ignored by people of note, and becoming desperate, Count von Zeppelin broke the bounds of tradition by soliciting donations from the public. He did this by writing an appeal in a widely circulated journal Die Woche.[27] Its main theme centered on having a German airship at the St. Louis World's Fair in 1904. Again, only a small amount of money came in. This was apparently his only attempt to secure public assistance.

Spurned by the government, by the engineers, by the notables of the Reich, and by the German public, Zeppelin now turned to his old friend King Wilhelm of Württemberg. For reasons of friendship, rather than belief in Zeppelin's invention, the King authorized a state lottery that raised 124,000 M. Moreover, although Wilhelm could not induce

the Prussian state government to permit the sale of the lottery tickets within its borders, he did persuade them to contribute another 50,000 M.[28] Realizing that even the combined total of the sums at his disposal were about a quarter of what he needed, the Count reluctantly mortgaged his wife's estates in Livonia to raise 400,000 M. more. He also persuaded Carl Berg to grant such generous credit terms on the aluminum for the framework that it was practically a gift. Likewise, Gottlieb Daimler supplied the engines chiefly for the publicity obtained.

Thus was Zeppelin able to build his second rigid airship. His chief engineer, Ludwig Dürr, had already been preparing the design. Slightly smaller than the _LZ 1_, the _LZ 2_ was to be some 414 feet long and 38.5 feet in diameter.[29] The 16-sided rings were to separate 16 gas cells containing an aggregate of 366,200 cubic feet of hydrogen. The aluminum for the _LZ 2_ was alloyed with zinc and copper for additional strength; unfortunately the alloy lacked uniformity. The longitudinals, at Dürr's suggestion, were made of triangular section girders, a vast improvement over the I beams of the _LZ 1_ that was to be retained with only slight modifications over the years. The 850 pound, 14 horsepower engines of the _LZ 1_ illustrated the remarkable development in this field when compared to the 425 pound units of 15 horsepower each the Daimler plant delivered

for the LZ 2. These comparatively powerful engines drove larger three-bladed propellers somewhat over seven feet in diameter.

Construction of the LZ 2 began in April, 1905, in the rebuilt floating hangar that now rested on piles at the edge of the Bodensee. Within seven months, it was ready for its trial flight. On November 30, the airship was towed from the shed. A knot in the tow rope, however, jammed when the release mechanism was triggered and the bow of the LZ 2 was pulled into the water, damaging the elevators and rudders that had been placed under the hull in lieu of the sliding weight.

The chapter of accidents and failures, which is the early history of this industry, continued when the LZ 2 was brought out for a second time on January 17, 1906. On this occasion, while the ship was able to rise above the Bodensee, the rigid proved to be vertically unstable against a strong southwest wind. Soon both engines had failed: the forward one because the fans drawing air through its radiators broke down; the one in the car aft the victim of a broken clutch spring. Powerless, the airship was blown to the northeast near Kisslegg in the Allgaü. Here Zeppelin managed to bring the LZ 2 down with only minor damage to the stern when it struck some trees. The crew tied the airship down for the night and the Count confidently expected to repair the engines, patch the stern, and fly

back to the Bodensee the next day. During the night, however, strong winds arose again which beat the dirigible against the ground so severely that it had to be dismantled. In a despairing mood, Zeppelin publicly declared that he would build no more rigid airships.[30] Yet a few weeks later, he was calling on Hugo Eckener, a correspondent for the Frankfurter Zeitung who had reported on Zeppelin's airships. Concerned that his experimental flights were not reported correctly, Zeppelin urged Eckener to revise certain factual mistakes he had made in his account of the misfortune of the LZ 2.[31] Eckener was persuaded to reverse his opinion about the rigid airship and its inventor. Convinced of the power of the press, he undertook to write articles to educate the public about the value of the Count's work. Zeppelin agreed to let the newspaperman do what he could to help, even though he considered Eckener's suggestions futile. Indeed, they might have been futile but for events that were taking place in neighboring France.

In December, 1905, the French Army had accepted a comparatively efficient, practical semi-rigid airship designed by the French Lebaudy brothers. In the following February it had ordered another one. With this act the outlook for airships in Germany immediately improved. The Kaiser was moved to appoint a military commission to consider what type of airship would best counter the French action.[32]

With the total loss of the LZ 2 before them, they could hardly recommend Zeppelin's rigid type ship. Needing a small short-range craft for tactical scouting, an order was placed with August von Parseval for several blimp-type ships, the first of which was completed later that year.

Nevertheless, help was forthcoming for Zeppelin. The commission recommended an Imperial gift to him of 100,000 M. and suggested that permission be given to hold a lottery for the Count in Prussia. The Minister of War backed the idea. A sum of 250,000 M. was eventually raised. The Airship Study Association, a group heretofore connected only with the Parseval endeavor, also contributed another 100,000 M.

By May of 1906 Zeppelin had begun work on this third dirigible, the LZ 3. With dimensions essentially the same as in the ill-fated LZ 2, the gas volume was increased to 403,600 cubic feet. Additional elevators were fitted forward of the front car and aft of the rear one. Two pairs of large horizontal stabilizing fins were added to the rear of the hull to eliminate the vertical pitching of the LZ 2 (see tail fin drawings on next page). Innovations like this came only after the need for them had been experienced: the only fundamental aerodynamic research was done in a wind tunnel Dürr had improvised at his own expense.[33]

The LZ 3 took to the air on October 9, 1906, and attained a speed in excess of 24 miles per hour while

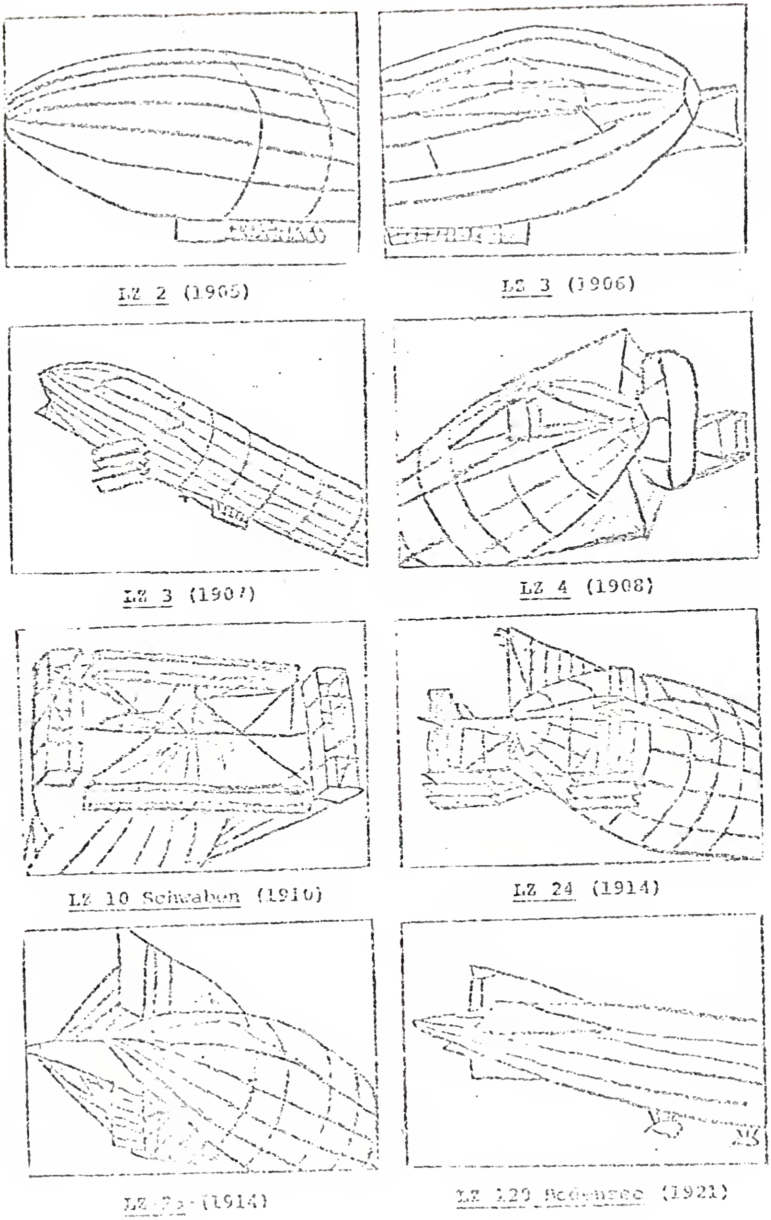

Figure 4: Evolution of the design of the control surfaces of Zeppelin airships.

carrying 11 people and some 5,500 pounds of ballast. After remaining airborne for two hours and seventeen minutes, the airship was brought to rest on the Bodensee again with no ill effects. A second flight the next day proved equally successful.

Even Major Gross, whom the Count considered to be inimical to his plans, now recommended that Zeppelin be given half a million marks to continue his efforts to develop a militarily useful craft. The inventor himself was now as elated as he had been depressed after the loss of the LZ 2. He wrote a letter to the Imperial Chancellor on December 1, 1906, suggesting that the government should not only buy the LZ 3 for a half million, but also two similar ships for like amounts:

> I can assert today that I can demonstrate the possibility of constructing airships with which, for instance, 500 men with full combat equipment can be carried for the greatest distances. These airships, because they will contain no gas, will be extremely safe, and in respect to housing arrangements as well as building and operating costs will be comparatively very inexpensive.[34]

The letter was forwarded to the War Ministry, where someone covered its margins with comments like "If only we had millions!" "Impossible!" "Don't even think about it!"[35] Yet Chancellor Bernhard von Bülow supplied Zeppelin with a half million marks to continue his work.[36] The government also undertook to buy the ship if it were able to make an uninterrupted 24 hour flight.[37] At last Zeppelin could proceed with his experiments.

All through 1907 modifications were made to the LZ 3. The triangular keel was extended from the gondolas to both ends of the hull and the control surfaces beneath the body of the airship were replaced by quadruplane elevators mounted low on the sides of it at the points where the cylindrical body began to taper toward the extremities of the vessel. The positioning of the elevators made the paired rudders less effective, and under the best of conditions they had to be fully deflected before the LZ 3 would begin turning.

Five flights in September (on at least two of which representatives of the Navy and the Army, including the ubiquitous Major Gross, were aboard) demonstrated the practicality of using the elevators to take off. Although one of these flights lasted almost eight hours, Zeppelin realized that the LZ 3 simply was not capable of undertaking a 24 hour flight and that he would have to construct a new and larger airship for the test.[38] A visit by the German Crown Prince was the occasion for the last routine testing flight of the LZ 3 in 1907 on October 8. The badly leaking airship was then laid up for the winter. On December 14, a severe storm tore the hangar from its moorings and piled it up on shore, doing considerable damage to both the shed and the deflated airship suspended within.

Meanwhile word of the successful flights of the LZ 3 had reached General Helmuth von Moltke, Chief of the General

Staff. Upon examining the favorable reports, he became convinced that Zeppelin's airship was the only hope of having something superior to France's efforts. He arranged that the Count should be given 400,000 M. for a fourth dirigible. If this vessel could complete a 24 hour flight over a distance of 435 miles, the army would purchase both the new ship and the LZ 3 for 2,150,000 M.[39] The financial backing which Zeppelin so badly needed now seemed within his grasp.

On June 2, 1908, the completed metal skeleton of the LZ 4 was towed out to the reconditioned hangar and the damaged LZ 3 was returned to the old hangar on shore. Basically an enlargement of the LZ 3, the new airship was 446 feet long, 42.5 feet in diameter, and capable of holding some 530,000 cubic feet of gas in 17 cells. Useful load under "standard conditions" was increased to 10,150 pounds and more powerful 105 horsepower Daimler engines raised the top speed to 30 miles per hour.[40] A small cabin with two windows was placed amidships, and from it a vertical shaft ran between two gas cells to a platform on top, useful as a position for taking navigational sights (or emplacing a machine gun, as was done later). Whereas the horizontal elevators and stabilizing fins remained as on the LZ 3, small rectangular rudders were placed at the bow and stern.

The airship's first flight lasted only 18 minutes. Immediately after taking off, it began to circle

uncontrollably over the lake and the only corrective measure the Count could take was to bring it back down.

The small bow rudder was removed and two small single rudders were fitted between the stabilizers as on the LZ 3. After another trial flight on June 23, the rudders between the stabilizers were doubled, large vertical fins were added above and beneath the stern, and a large oval rudder 26 feet high and 16-1/2 feet across was hinged behind these. The third try proved successful, for on June 29 the airship answered the helm smoothly.

Satisfied that the steering problem was the last problem to be eradicated, Zeppelin had the LZ 4 stocked with sufficient supplies for a 14 hour flight and set out cross country over Switzerland on July 1. Following a route over Schaffhausen to Lucerne, the LZ 4 returned to Manzell via Zurich, covering some 240 miles. Despite having to fight a head wind all the way back, the airship covered the route in only 12 hours. This flight, fully reported by Eckener in the press, brought the Count to the attention of newspaper readers throughout Germany. Its very success probably caused him to ignore another problem encountered on the flight. No system existed to provide a continuous supply of fuel for the engines; therefore, when each tank (containing 440 pounds) neared empty, the engine had to be shut off while additional fuel was carried down from the gangway in 44 pound containers.

Convinced that fulfilling the time and distance conditions set forth by the Minister of the Interior and the Chief of the General Staff could be met by cruising from the Bodensee to Mainz and back in 24 hours, the Count had the LZ 4 filled with fresh hydrogen to provide the maximum lift.[41] Thus began a new chapter of misfortunes and disappointments. A few minutes after a good lift off on July 14, the forward engine fan threw a blade, and the airship was forced to return to its base, postponing the planned flight for a day while the damage was repaired. As the LZ 4 was being eased out of its berth the next day, it struck the side of the hangar. The damage was fairly extensive: several rings and longitudinals were cracked or broken; the port after propeller was mauled; the elevator nearest it smashed; and at least three gas cells were holed. Repairs took nearly three weeks, delaying the departure of the LZ 4 until August 4, when it lifted off the Bodensee shortly after 6:00 A.M., carrying enough fuel, oil and reserve radiator water for 31 hours. It also carried 12 people and their supplies and personal items, and some 1,450 pounds of ballast.[42]

As all this constituted a rather heavy load for the LZ 4 (especially as a three-week delay since inflation meant some loss of gas), the Count was obliged to fly at a low level to preserve his ballast. He directed the helmsman to

steer a somewhat indirect course for Mainz via the Rhine valley. News of the impending flight had been provided by Eckener and word of the approach of the airship was telegraphed ahead. At Konstanz, at Schaffhausen, and at Basel crowds of curious and awestruck people covered the streets, balconies, and rooftops staring at the LZ 4 as it cruised overhead.[43] At Basel, the airship was turned north. Having covered almost a hundred miles in three hours, Zeppelin saw no reason why they could not make the remaining 180 miles in eight more hours and begin the return trip around half past five. At Strassburg, then a German city, the airship sailed past the cathedral below the top of its tall spire while more crowds gathered in the streets to watch.

Misfortune then struck. At 12:57 P.M., the forward engine had to be stopped while fuel was poured into its tank. The LZ 4, which had previously been held at low altitude by using the motors to drive it at a slight downward angle to offset the increased buoyancy as the sun warmed the gas, now climbed to 2,700 feet which was well above the pressure height. Large quantities of hydrogen escaped through the automatic valves, making the ship heavy. After the forward engine was restarted, a near collision with a bridge compelled the dumping of 132 pounds of ballast. At 1:58 P.M., the after engine had to be stopped. The

airship rose to 2,900 feet and more gas was lost. Past the city of Worms, the after engine had to be stopped again and once more the LZ 4 rose, this time to 3,380 feet. More hydrogen was valved off. Some two hours later, at 4:05 P.M., the forward engine was shut down when a gear in the fan drive broke.

After another attempt to go on, Zeppelin brought the LZ 4 to a smooth landing on the Rhine 14 miles south of Mainz at 5:24. The gear was replaced in 20 minutes, but the airship was too heavy to lift off. Empty fuel cans and all extra equipment were removed; in addition, five crewmen were put ashore. Dropping ballast, the LZ 4 lifted from the water again at 10:20 P.M. and reached Mainz a half hour later. Here the airship was turned south and had to be repaired. At 1:27 A.M., with the LZ 4 just past Mannheim, the forward engine crank bearing melted. The airship was actually blown back after the engine had to be stopped for refueling south of Stuttgart.

Unable now to meet the conditions laid down for a 24 hour flight, Zeppelin decided to land the LZ 4 and bring Daimler repairmen from nearby Untertürkheim to repair its forward engine. The airship landed smoothly at 7:51 A.M. near a village called Echterdingen southwest of Stuttgart.

Curious sightseers soon thronged the countryside while the dirigible was anchored as firmly as possible pending the arrival of a detachment of soldiers from Stuttgart

to guard the airship and serve as its ground crew. Daimler engineers removed the disabled engine and set up a repair shop some distance away. Once all necessary arrangements had been put in order, Zeppelin retired for a nap in the midships cabin. Awakening an hour later, he decided to go into Echterdingen.[44] Shortly thereafter, dark thunderclouds built up rapidly in the western sky. A little before 3:00 P.M., a sharp gust of wind caught the prostrate airship on its starboard, and the LZ 4 began to drift sideways. Unable to hold it, most of the soldiers let go of their lines, but a few were dragged a considerable distance before doing so, and two crew members were caught inside the airship. One of them dashed from the gondola aft to pull the gas valve controls in the forward car to the open position. The LZ 4 settled onto some trees a half mile from where it had been anchored and the two men scrambled out. As they did so a spark ignited the hydrogen spilling forth from one of the punctured cells in the bow. Instantaneously, flames broke out forward and raced aft.[45] Within moments all that was left of the LZ 4 was a smouldering pile of rubble and charred, twisted girders. An objective observer viewing Zeppelin gazing disconsolately upon the blackened wreckage of his dreams would be forced to conclude that the end had come. It had, in a way, but it was the end of the beginning.

About the opening phase in the development of the rigid airship two remarks might be made. The first is the enormous expense of the early airships. Zeppelin's early ships cost in the region of half a million marks each. Obviously this was not a field for the little entrepreneur or investor. Like most of this contemporary German inventors, Zeppelin had to turn to the state for help.

Another remark which might be made concerns the Count's intense patriotism. It is impossible to estimate how powerful was his ever-constantly expressed wish to serve his country, but it must have made a great deal of difference to him. So powerful was this motivation that neither defeat nor ridicule could divert him from what he had to do. A man so possessed with an idea had to find a way to achieve its fulfillment. Fortunately for him there now occurred "the miracle of Echterdingen."

NOTES

1. It leaked badly, had no aerodynamic stability, and was impossible to control. Written report by Ernst Jagels, November 6, 1897, quoted in Berg, David Schwarz, pp. 12-6.

2. Letter, Hans von Schiller to A. D. Topping, reporting on an examination of Count von Zeppelin's diaries and papers, in "Count Zeppelin's American Balloon Ascent (IV)," Wingfoot Lighter-Than-Air Society Bulletin, Vol. XIII, No. 5 (March, 1966), p. 9 and Eckener, Graf, pp. 104-6.

3. Eckener, Graf, pp. 105-6.

4. This was done with the LZ 3. Years later, the commanders of the American Navy rigids discovered the technique and introduced it as something "new."

5. Eckener, Graf, pp. 105-6.

6. Ibid., pp. 108, 112.

7. Germany, Militärgeschichtlichen Forschungsamt, Die deutschen Luftstreitkräfte, Letter, "Generalleutnant z. D. Graf von Zeppelin an den Chef des Generalstabes der Armee," September 14, 1893, document #11, p. 13.

8. As reproduced in Hans Hildebrandt (ed.) Zeppelin-denkmal für das Deutsche Volk (Stuttgart: Germania-Verlag, 1925), pp. 304-7.

9. Heinrich Müller-Breslau, "Zur Geschichte des Zeppelin-Luftschiffes," Verhandlung zur Beförderung des Gewerbfleisses (Berlin: n.p., 1914), p. 35.

10. Germany, Militärgeschichtlichen Forschungsamt, Die deutschen Luftstreitkräfte, Letter, "Generalleutnant z. D. Graf von Zeppelin an das Kriegsministerium," October 21, 1894, document #16, pp. 19-24.

11. Ibid., "Kommissionsbericht über die Prüfung neuer Entwürfe des Grafen Zeppelins," March 2, 1895, document #17, pp. 24-5.

12. *Ibid.*, pp. 24-6.

13. Eckener, *Graf*, p. 143.

14. Berg, *David Schwarz*, p. 43.

15. They were actually narrow openwork I beams about seven inches deep. Much of the technical data in the description of the LZ 1 and other early craft is taken from Hildebrandt, *Die Luftschiffahrt*, pp. 164-216 and Douglas H. Robinson, *Giants in the Sky* (Seattle: University of Washington Press, 1973), pp. 23-5.

16. Berg, *David Schwarz*, p. 44.

17. Robinson, *Giants*, p. 25.

18. Berg, *David Schwarz*, p. 44.

19. An airship is "weighed off" when its load and lift have been equalized or the difference determined. When an airship is described as "weighed off," it is in balance, but "weighed off two hundred pounds heavy" means that the airship must employ some aerodynamic means to become airborne although the shape of the hull was usually sufficient for this small amount.

20. Thomas E. Curtis, "The Zeppelin Airship," Smithsonian Institute *Annual Report, 1900* (Washington: Smithsonian Institute, 1901), p. 220.

21. As quoted in *Ibid.*, p. 222.

22. Hildebrandt, *Die Luftschiffahrt*, p. 168.

23. T. E. Guttery, *Zeppelin, An Illustrated Life of Count Ferdinand von Zeppelin, 1838-1917* (Aylesbury, Bucks, U. K.: Shire Publications Ltd., 1973), p. 26.

24. Alfred Colsman, *Luftschiff Voraus! Arbeit und Erleben am Werke Zeppelins* (Stuttgart: Deutsche Verlags Anstalt, 1933), pp. 55-7.

25. Berg, *David Schwarz*, p. 46.

26. Eckener, *Graf*, p. 144.

27. *Ibid.*, p. 49.

28. *Ibid.*, pp. 49-50.

29. See Appendices A and B for comparative information on all rigid airships.

30. Eckener, <u>Graf</u>, p. 151.

31. Germany, Militärgeschichtlichen Forschungsamt, <u>Die deutschen Luftstreitkräfte</u>, "Die Wahrheit über mein Luftschiff," Appendix to Letter, "General der Kavallerie z. D. Graf von Zeppelin an den Kriegsminister," February 10, 1906, document #25, p. 44.

32. Lieutenant General of Transport Troops von Werneburg, Lieutenant Colonel von Werner, Major von Besser, Major Erich Ludendorff of the General Staff, Major Meister, Major Oschmann, Captain Gross, Captain Meyer, Captain Sperling, and First Lieutenant George. <u>Ibid.</u>, "Protokoll über die erste Sitzung der Kommission zur Beratung der Frage des Baues von Motorluftschiffen am 29. Januar 1906," document #24, pp. 40-1.

33. Robinson, <u>Giants</u>, p. 32.

34. Germany, Militärgeschichtlichen Forschungsamt, <u>Die deutschen Luftstreitkräfte</u>, "Antrag des Generals der Kavallerie z. D. Graf von Zeppelin an den Reichskanzler (Reichsamt des Innern) auf Erwerb seines Luftschiffes durch das Reich," December 1, 1906, document #26, pp. 46-9.

35. <u>Ibid.</u>

36. <u>Ibid.</u>, "Immediatbericht des Reichskanzlers an den Kaiser über Massnahmen zur Förderung des Zeppelin-Projektes," February 25, 1907, document #28, pp. 57-8.

37. <u>Ibid.</u>, "Die Inspektion der Verkehrstruppen an das Allgemeine Kriegsdepartement," March 12, 1907, document #29b, p. 59.

38. Eckener, <u>Graf</u>, pp. 155-6.

39. <u>Ibid.</u>, p. 156.

40. "Standard conditions" means at sea level, in warm, dry weather.

41. The gas cell material was still far from leak-proof. The <u>LZ 3</u>, for example, had lost 2,100 pounds of lift in less than two weeks the previous year (1907).

42. Georg Hacker, *Die Männer von Manzell* (Frankfurt am Main: Societäts-Druckerei, 1936), p. 82.

43. *Ibid.*, pp. 83-4.

44. *Ibid.*, p. 99.

45. Account of an eyewitness quoted in Goldsmith, *Zeppelin*, pp. 170-1.

CHAPTER IV

THE PHOENIX: FROM FAILURE TO SUCCESS

No sooner had a chastened and dejected Count von Zeppelin departed from Echterdingen than David Lloyd George (the future British prime minister) arrived:

> We went along to the field where the giant airship was moored, to find that by a last minute accident it had crashed and been wrecked. Of course we were deeply disappointed, but disappointment was a totally inadequate word for the agony of grief and dismay which swept over the massed Germans who witnessed the catastrophe. There was no loss of life to account for it. Hopes and ambitions far wider than those concerned with a scientific and mechanical success appeared to have shared the wreck of the dirigible. Then the crowd swung into the chanting of "Deutschland, Deutschland Über Alles" with a fanatic fervor of patriotism. What spear-point of Imperial advance did this airship portend?[1]

Echterdingen was the culminating manifestation of the process whereby the rigid airship came to be adopted by the German people as an object of intense national pride.

Count von Zeppelin, unaware of what was happening around the charred remains of LZ 4, arrived at Friedrichshafen late on the night of the disaster. Word of the wreck had preceded him. The bunting that had been hung in the city in honor of the triumphal return of the LZ 4 had all been removed. Flags flew at half mast.

What took place then has been described as "the miracle of Echterdingen." Moved by the newspaper accounts of the disaster, a torrent of money swept into the offices of the Zeppelin Corporation. Passengers on a pleasure boat on the Bodensee donated 600 M. A bowling club in Baden sent 150 M. A little girl wrote:

> Mommy carried me from my bed out on the balcony. The sky was dark with many stars, and I saw the Zeppelin and heard its humming noise. It was so pretty. But on the next day we heard the terrible news that the beautiful airship had burned up. Then I cried a great deal and told Mommy to send to the Count everything in my bank, so that he could build a new airship.[2]

The amount of money in her letter was a few pfennigs. The total amount received the first day exceeded 400,000 M.; more than enough to replace the LZ 4. The Deutscher Luftfahrerverband (German Association of Aviators) published an appeal for contributions to a national fund for the construction of Zeppelin-type airships while the Schwäbischer Merkur, the leading newspaper in Stuttgart, started a fund of its own with a contribution of 20,000 M. The appeal in the Schwäbischer Merkur was reprinted in papers throughout Germany; similar newspaper articles appeared elsewhere. The response was extraordinary. Not only did large contributions come from wealthy industrialists and manufacturers' associations, but sums of one or two marks also came in from thousands of individuals. For several weeks more, a deluge of letters continued to

pour upon the Count's headquarters in Friedrichshafen--most of them containing money. It was not the Imperial Government, but the German people (motivated by their sense of national pride) who responded to the disaster at Echterdingen. By showering Count von Zeppelin with money they converted his worst disaster into his greatest triumph.

The rigid airship thus became the first and only invention to be financed by public donation. When all the contributions were added together, it was found that the German people had given 6,098,555 M.[3] Never again would Count von Zeppelin's plans suffer from lack of funds. Not until after the First World War (and Zeppelin's death) would the development of his invention be hampered for lack of money.

On September 3, 1908, his financial needs now met, Count von Zeppelin proceeded to establish the Luftschiffbau Zeppelin G.m.b.H. (Zeppelin Airship Construction Company) with a capital of 3,000,000 M. A few months later, as still more money became available, Count von Zeppelin increased this initial capitalization to 4,000,000 M. On December 30, 1908, the remaining donations were used to endow the Zeppelin Stiftung (Zeppelin Foundation), with Zeppelin as its chief executor. Its purpose was to establish subsidiary companies needed to provide components

and services; it was also meant to provide control over them without overburdening the administrative staff of the Luftschiffbau, which was to concentrate on technical development.[4]

While plans for the LZ 5 took shape on the drawing board, rebuilding of the earlier damaged LZ 3 in the shore hangar at Manzell began within days of the turn of events at Echterdingen. Although the LZ 4 had not fulfilled the conditions specified, the Minister of the Interior (Theobald von Bethmann-Hollweg), perhaps swayed by the popularity the Count was enjoying, advocated purchasing the LZ 3 as soon as it was reconstructed along the lines of the LZ 4.[5] Opposition was raised by the realist General von Einem, the Minister of War, who doubted that the LZ 3, even if substantially modified, could equal the performance of the LZ 4 before its loss. Without avail, he advised that the LZ 3 be put through a performance test before it was purchased.[6]

Meanwhile, repairs and major alterations on the LZ 3 continued. The midships section was split to provide space for an extra bay and another gas cell which increased the gas capacity of the airship by 27,000 cubic feet. A large vertical fin was added to the stern to improve stability. By the substitution of two more powerful Daimler engines for those previously installed (105 horsepower

compared with 85 horsepower), the maximum speed was increased to nearly 28 miles per hour.[7]

On October 21, 1908, work on the LZ 3 was completed, and three short test flights were made within the following week. On October 27, the Kaiser's brother, Admiral Prince Heinrich, was an observer on board a flight of nearly six hours duration. Having learned that the Kaiser and his family were vacationing at Donaueschingen, some 50 miles from Friedrichshafen, Count von Zeppelin decided to demonstrate the LZ 3 by flying it over the castle where the Kaiser was staying. When the airship lifted off on November 7 to make this flight, the Crown Prince, an early airship enthusiast and supporter of the Count, was riding in the forward gondola. Despite encountering some inclement weather and unfavorable winds, the LZ 3 reached Donaueschingen without difficulty and circled overhead while the Kaiser and his retinue watched from the courtyard. Delighted with the obvious interest shown by those below, Count von Zeppelin then returned the LZ 3 to Manzell.[8]

The importance of this flight was underscored by two events that occurred within a few days. On November 9, the Count received a telegram notifying him that the cabinet had at last reached a decision concerning his airships. Despite the aforementioned opposition of the War Minister,

they had resolved to purchase the LZ 3, which then became army airship Z 1.[9] The following day, November 10, the Kaiser and a host of courtiers arrived by special train to honor Count von Zeppelin with a personal visit. After a tour of the facilities, the visiting dignitaries watched as the LZ 3 was put through its paces and made a short flight to Friedrichshafen. The Kaiser declined an invitation to go aloft, but congratulated the Count and decorated him with the Prussian Order of the Black Eagle.[10]

Shortly thereafter, on March 1, 1909, the first military crew arrived at Friedrichshafen and eight days later began training with the airship now officially designated as the Z 1. After a flight to Munich during April 1-2, full responsibility for the airship was turned over to the Prussian Airship Battalion.[11] As the hangar being built for it inside the fortress of Metz was not yet ready, the Z 1 was moved on May 9 to a temporary tent hangar on land leased from the city of Friedrichshafen for 50 years and intended to be the permanent base for Luftschiffbau Zeppelin.

The Z 1 remained there until June 29 when, under the command of Major Sperling of the Prussian Airship Battalion, it departed for Metz. A cloudburst forced a landing at Mittel-Biberach, while further storms and high winds prevented a resumption of the trip until July 3. Reaching

Meta, the Z 1 remained there as the Army's training airship until it was dismantled in March, 1913.[12]

Meanwhile, the LZ 5 had made its initial flight on May 26. Basically identical with the LZ 4 in appearance, the new airship incorporated minor but important alterations. There was no lower vertical fin as it was thought that the airship would steer better without it; there was no cabin in the gangway amidships; the rear propellers were made reversible so as to be able to decrease the forward speed when landing; most importantly, small fuel tanks were added to each gondola to keep the engines running while the main tanks were being refilled.

Soon, word of Count von Zeppelin's plans to make an extended 36 hour flight to test the new airship's capabilities had reached several newspapers. Mention having been made that the flight might go to Berlin, the press seized upon this as the flight's main objective. Interest in Berlin was aroused. In the event, when the test flight was begun, strong headwinds forced Zeppelin to abandon his proposed visit to Berlin. An irked Kaiser wired Zeppelin:

> Since 5 pm I have been waiting with Her Majesty the Kaiserin and the princes and princesses at the Tempelhof Field for Your Excellency. Together with the leading officials and personnel of the . . . Regiments, which, giving up their Whitsunday leave, had hastened here to assist Your Excellency . . . . Your Excellency owes it to the Berliners to make them special amends. I request Your Excellency to advise by return mail when you will come to Berlin with

> the airship; since I will begin a Scandinavian vacation on August 29, the flight cannot be later.[13]

But the Count had far more important things to worry about than getting to Berlin. Thirty-six hours after he had taken off, with his crew exhausted and his fuel almost gone, he had crashed into a tree when making an emergency landing in the vicinity of Heilbronn. The repaired airship did not arrive back at Friedrichshafen until shortly after 6:00 on the morning of June 2, almost 81 hours after it had departed on its ill-fated so-called "Berlin flight."

Despite its misadventures, the LZ 5 was rebuilt with no modifications. It was believed (with good reason) that the damage done at Heilbronn was due to human error rather than to mechanical failure. On July 24, 1909, the government commission on board for a trial flight tentatively accepted the airship pending its delivery to the new Airship Battalion hangar at Cologne. Before the LZ 5 (now renamed the Z II) was turned over to the army, Count von Zeppelin applied for and received permission to take it to the International Aviation Exposition being held at Frankfurt am Main.[14]

Starting north with the Z II on July 31, the airship made slow headway against the headwinds and thunderstorms it encountered. It took nearly 12 hours to cover the 243 miles to Frankfurt. As that city had no shed large enough

to house the rigid airship, Count von Zeppelin decided to push on to the hangar in Cologne as soon as possible. Despite a forecast of thunderstorms, he gave the order to lift off on August 2. Severe squalls and powerful headwinds however soon forced the Z II to return to Frankfurt. On the next day another attempt to depart was thwarted when the starboard propeller aft broke and some of the pieces penetrated a gas cell. Repairs took two days; the airship finally left for Cologne on August 5.[15]

As a result of tests carried out by the War Ministry between October 25 and November 5, 1909, it was decided that no further dirigibles would be purchased by the government until their performance had been improved.[16] None of the airships tested (the Z II was matched against the semi-rigid M II of the Airship Battalion and the non-rigids, the P I and PL 3, built by August Parseval) could fly 250 miles at an altitude of 3,300 feet; nor could they develop sufficient speed to be useful in all weather (the mean speed of the Z II was 28 miles per hour and a speed of from 36 to 38 was regarded as necessary). Likewise, none could maintain an altitude of 4,000 feet. The Z II could not exceed 3,450 feet.

On April 25, 1910, some five months after the tests, the Z II was scheduled to take part in a flight to Hamburg, where the Kaiser was vacationing. It was on the return

journey that bad weather conditions forced the Z II to land near Lemberg. A squall having jerked it away from the men holding it, the airship, like a giant whale, followed a random path up the Lahn Valley, and became a total wreck on the railroad line near Weilburg 15 miles away. Once more, Zeppelin's mercurial career had turned from triumph to disaster. The misgivings of his opponents at the War Ministry had been confirmed.

Weilburg was Zeppelin's spring crisis; by the fall of 1909 he was faced with a second Berlin crisis. Commanded by the Kaiser to appear in Berlin before August 29, Zeppelin rushed the LZ 6 to completion. With a hull identical to LZ 4 and LZ 5, this airship had an entirely new system for transmitting power from the engines to the propellers. The drive shafts and bevel gears to the propellers (located on the sides of the hull some distance above the gondolas) were replaced by a steel band drive from engines of an improved 115 horsepower type. The vertical stabilizing fins were eliminated and an open platform with a railing around it took the place of the small cabin in the gangway amidships. Probably the most distinguishing feature of the LZ 6 was a rain skirt fitted to the hull at the midships longitudinal. Of stiff material four inches long, it was supposed to prevent rainwater from running down the side of the hull to drip on those in the gondolas below; instead, it acted as a small sail

and fluttered in the wind, reducing the speed of the LZ 6.

The airship was completed on August 25 and Zeppelin dispatched it to Berlin two days later.[18] Less than three hours out, the band drives of the LZ 6 to the forward port propeller broke. The helmsman had to climb out on the propeller bracket to fit a new one from the spares carried aboard. Shortly thereafter, one of the cylinders in the forward engine cracked, necessitating its shutdown. Rain made the airship heavy, and, when one of the wires controlling the ballast sacks broke, the LZ 6 was brought down on the Dutzendteich, a lake near Nuremberg, for repairs. The dirigible was airborne again several hours later but it continued to suffer mechanical problems. The forward engine broke down over Bayreuth at 7:00 A.M. and had to be repaired. Seven hours later the forward port drive band broke again. In addition, a propeller and its shaft fell off. Running on three propellers, the LZ 6 reached Bitterfeld by 6:30 P.M. Here it was joined by Count von Zeppelin. Early on the morning of August 29, the airship departed Bitterfeld for Berlin, arriving there with no more trouble five hours later.[19]

After circling the capital for an hour and a half, the Count brought the LZ 6 down on the Tegel rifle range in front of the Kaiser and the leading officials assembled

there to greet him. That evening the Kaiser entertained Count von Zeppelin and his crew as guests at the Imperial palace in Potsdam before they departed for the return trip.

The outward flight was as plagued with troubles as the inward flight to Berlin had been. Shortly after lift off, late the evening of August 29, the steel band drive on the forward starboard propeller broke and the propeller shattered before it fell off, sending one of its blades through a gas cell. Once again the LZ 6 was forced to land, this time in a forest clearing. It was tethered to the ground for three days while emergency repairs were carried out. The flight was resumed late in the evening of September 1, and the LZ 6 reached Manzell late the following day.

On September 11, 1909, the LZ 6 was flown to the International Aviation Exposition in Frankfurt am Main for publicity purposes. It was brought back to Manzell on September 19 for further tests and modifications. A radio built by Telefunken was used aboard for the first time, and on October 20, the LZ 6 flew with three engines. The new one (the first Maybach built especially for an airship) was mounted in the keel amidships replacing the railed platform. The top speed with the extra 140 horsepower engine reached 36 miles per hour. The engine amidships was soon removed, however, lest it ignite the hydrogen

valving off from one of the cells at pressure altitude.[20]

On October 27, the LZ 6 was transferred to the tent hangar at the new base north of Friedrichshafen where it was deflated and stripped of its outer covering pending reconstruction. The new permanent hangar in the center of the field was nearing completion, and after it was finished, the framework of the LZ 6 was hand carried to it on February 12, 1910. The LZ 6 was lengthened by adding another bay (and gas cell) in the center while the gondolas beneath were modified so that the Maybach engine occupied the forward car and the two Daimler engines the one aft. A vertical fin was added above the horizontal stabilizer while small rudders added below displaced the large oval-shaped rudder inherited from previous designs. On a trial flight, the rebuilt LZ 6 attained a speed of nearly 35 miles per hour. Despite all these improvements and the tests that had been carried out, a skeptical War Ministry refused to buy it.[21]

Faced with the government's reluctance to purchase the LZ 6, Zeppelin was persuaded by his business manager, Alfred Colsman, to set up an airline to fly passengers.[22] There were, after all, more people wanting to fly in airships than there were dirigibles to carry them. The public had launched the air age; the public would also provide

the customer demand that would ensure its expansion; or so at least Colsman thought. Reluctantly the Count (whose motivation had been service to his country rather than commercial gain) agreed.[23] On November 16, 1909, the Deutsche Luftschiffahrts Aktien Gesellschaft (known as DELAG) came into existence, with its headquarters at Frankfurt am Main. With this, the commercial chapter of the life of the dirigible in Germany opened.

It soon became evident that Colsman knew what he had been talking about. For the exclusive rights to sell tickets in the new venture, Albert Ballin (1857-1918), the director of the Hamburg-Amerika Steamship Line, provided 100,000 M. per year. Major German cities, increasingly caught up in the aviation fever, provided most of the necessary capital of the new organization and strove to outdo one another in the construction of airship hangars. Here was an unsuspected bonanza. The solving of the engineering problems of a new industry was accompanied by equally significant commercial change.

On its formation, in November 1909, DELAG immediately ordered a new rigid airship from the Luftschiffbau. This became the <u>LZ 7</u> (or <u>Deutschland</u>, as it was named). With a length of 486 feet and a diameter of 46 feet, this airship was larger than any of its predecessors. It was distinguished by a comparatively pointed bow and a bluntly rounded stern. Its 18 gas cells contained over 680,000

cubic feet of hydrogen giving a useful lift of 11,000 pounds in comparison with the LZ 1, which had only 1,340 pounds of useful lift. This lift was divided among fuel and oil, water ballast, the crew of eight or nine, and the 24 passengers. Three 125 horsepower Daimler engines drove the airship along at a maximum of 37 miles per hour.[24]

Completed on June 19, 1910, the airship was given four test flights by June 21, and then turned over to Captain Kahlenberg, formerly of the Prussian Airship Battalion, who had been hired by DELAG to command it.[25] Since Düsseldorf had been the first city to complete its hangar, the Deutschland was flown there the next day.

Six days later, on June 28, 23 journalists were invited aboard for a three-hour flight with a light breakfast of champagne and caviar served shortly after lift off in the cabin amidships. This cabin was described in one of the company pamphlets as being an extraordinarily comfortable and elegant room with mahogany (plywood) walls, a carpeted floor, and large sliding windows permitting an unhindered view in all directions.[26] If one will dwell for a moment on the conditions that have accompanied the introduction of any new form of transportation, it becomes rather obvious that the conditions surrounding the first passenger service in the air were unique. However, as the journalists were soon to discover, comfort can be deceiving.

Wishing to make a good impression, Colsman directed Kahlenberg to lift off at the appointed time, despite not yet having received a weather report.[27] Opting to cruise over the valley of the Wupper River rather than over the Rhine plain, Kahlenberg flew with the wind. The failure of one engine and the freshening of the wind on the return leg of the flight caused the Deutschland to be driven away from its base. Unable to halt the retrograde motion of the airship, Kahlenberg began throwing messages overboard requesting assistance wherever they might land.[28] The wind, however, drove them to a thunderhead over the Teutoberg Forest. The violent vertical currents of the stormfront tossed the airship to an altitude of 3,500 feet where much gas was lost through the automatic valves. Heavy from loss of gas and becoming increasingly ladened with rain, the Deutschland began to lose height. Out of control, the airship plunged to the forest below. The unhindered view from the central cabin (for it was still daylight) undoubtedly provided the journalists with more than they had bargained for.

By some quirk of fate the Deutschland alighted comparatively gently on top of the trees; no fire broke out and the only injury sustained was when one of the crew jumped from the aft gondola to the ground and broke his leg.[29] The airship, however, was a wreck. It had to be cut into sections, which were sent back to Friedrichshafen.

Hoping to salvage business operations for the summer of 1910, Colsman persuaded Eckener, who had been in charge of publicity for the Company since his meeting with the Count in 1906, to become flight director of DELAG in place of the unfortunate Kahlenberg. On August 21, the redesigned LZ 6 (which had been acquired to replace the Deutschland) was flown to a new base at Baden-Baden (near Karlsruhe) under Eckener's command.[30] Alas, Eckener's fortune at the outset was to prove no better than Kahlenberg's.

On September 14, because of engine failure, Eckener had turned back on a flight from Baden-Baden to Heilbronn. While mechanics were examining the engine to determine the cause of the trouble, others were cleaning the gondolas with the gasoline. When one of the engines was started a fire broke out and one of the mechanics, thinking he had a container of water, dumped gasoline on it. The resulting blaze quickly turned into a conflagration that destroyed the LZ 6. Still another dirigible had been wrecked.

Yet if ever an industry was able to rise phoenix-like from its ashes it was this one. Fortunately for DELAG, and the future of the airship, the LZ 6 had been covered by insurance with Lloyd's of London. The payment of 320,000 M. allowed DELAG to acquire from the Luftschiffbau Zeppelin another airship, the LZ 8, or Deutschland II. Completed

at Friedrichshafen on March 30, 1911, this airship was almost identical to its ill-fated predecessor of the same name.[31] Also like its namesake, it was based at Düsseldorf, arriving there under Eckener's command on April 11. Nothing could deter the public from wanting to fly in the new machines, and excursion flights were resumed there at the beginning of May.

Incredible as it may sound, the Deutschland II soon shared the fate of Deutschland I. On May 16, Eckener had all but decided to postpone the impending scheduled excursion flight because of high cross winds. However, a full load of passengers (each of whom had paid 200 M. for a sightseeing tour) was already on board and an expectant crowd awaited the lift off. Eckener gave the order for the Deutschland II to be brought out of the hangar. As the stern (airships were always put into the hangars bow first) cleared the wind screen, Eckener realized his error. A gust of wind caught the airship, dragging it sideways and lifting the ground crew off their feet. The stern rose in the air, swung over the wind screen and then crashed down upon it, impaled.[32] Once more, even though the frame was smashed, there was no fire. The passengers were rescued by fire ladders. The Deutschland II was almost a total loss.

One wonders with the aid of hindsight how these people could survive disaster after disaster. The historical fact

is they did. As long as they could find the money one dirigible followed another. Leadership was never in doubt. A few weeks after the loss of Deutschland II the Schwaben made its first flight on June 26, 1911.[33] Its acceptance flight was completed on July 15, and Eckener took it to the hangar at Baden-Oos. Shorter and easier to handle than its two predecessors, the Schwaben was also equipped with three of the Maybach 145 horsepower engines, with which it could attain the comparatively remarkable speed of 47 miles per hour. Henceforth, all DELAG airships were powered with the more reliable Maybach engines.

An improved system of technology, the ability to learn from past mistakes, improved training methods, better company organization, and first-class leadership (as with Eckener) all combined to make the DELAG a going concern. Greater distances soon became feasible. The Schwaben even flew to Berlin late in the season. For the longer trips (such as the Berlin flight) passengers willingly paid up to 600 M. For this they received not only the excursion but also dinners at small tables placed by the open windows where they were served from a menu featuring Rhine, Moselle, and Bordeaux wines as well as champagnes and cold dishes such as caviar, Westphalian ham, capon, and Strassburg pâté de foie gras.[34] In travel annals this kind of treatment was unique. Was this because only the very rich

could afford this kind of travel? It was entirely aristocratic.

While the *Schwaben* was laid up during the winter, a similar but slightly larger airship of the same kind was being completed at Friedrichshafen. Named the *Viktoria Luise* after the Kaiser's only daughter, it entered service at Frankfurt am Main on March 4, 1912.[35] As with the *Schwaben*, all of the control surfaces of the *Viktoria Luise* were located at the stern although the multiple rudders there were still suspended from the horizontal stabilizer. As of March 30, both the *Schwaben* and the *Viktoria Luise* were flying regularly. Seeing Germany from a DELAG airship became "the thing to do" for those who could afford it. In nine months the *Schwaben* carried 1,553 passengers at 200 M. per head.

Yet by now the reader will have learned that triumph in airship navigation was always short-lived. On June 28, 1912, friction between segments of torn gas cell fabric generated sparks that set the *Schwaben* afire while it was moored on the field at Düsseldorf. No passengers were aboard and no one was injured, but the *Schwaben* was a total loss.[36] As a result of researches carried out after this accident, Count von Zeppelin totally abandoned the rubberized fabric project of the Riedinger works and established under the auspices of the Zeppelin Foundation another subsidiary

company, the Ballon-Hüllen-Gesellschaft, to produce cells of goldbeater's skin.[37]

Nothing was able to impede flight. No sooner was an airship written off than another was in the air. As long as there was no loss of life, the public would not be put off. They were prepared to pay prices that enabled the company to write off one ship after another. Despite its setbacks, DELAG slowly expanded its sphere of operations. As DELAG was a subsidiary of the Zeppelin Foundation, and as such had a monopolistic access to Zeppelin airships for commercial purposes, it had no competition. The only other rigid airship builder (pp. 148-56), who had his own share of teething troubles, was still trying to interest the military. By 1914, DELAG flights between 13 German cities (ranging from Friedrichshafen in the south to Hamburg in the north, and from Düsseldorf in the west to Liegnitz in the east) had become commonplace.

One of the airships ordered from the Luftschiffbau Zeppelin as part of the expansion program in 1912 was the LZ 13 *Hansa*, which was identical to the LZ 11 *Viktoria Luise*. It was not completed until two months after the destruction of the *Schwaben*, however, and was put into service as its replacement. A third airship, the *Sachsen*, was delivered on May 3, 1913, to Leipzig, where it was based. With three airships (*Viktoria Luise*, *Hansa*, and

Sachsen) flying during the better part of 1913 and the first part of 1914, DELAG was sufficiently confident to order still another new airship, the LZ 26, designed to be a great improvement over previous rigids. This was delivered to the Army after the outbreak of war.[38]

In dealing with the commercial side of things we have left out of account the reaction of the military to the events we have described. It is known, for instance, that the success of the Schwaben, as reported by a number of junior general staff officers who had ridden aboard as passengers, had reached the ears of General von Moltke (the Chief of the General Staff). His interest aroused, he persuaded the Ministry of War to place an order with the Luftschiffbau Zeppelin. The result was the LZ 9, first flown on October 2, 1911, and designated by the Army as the Ersatz Z II. Similar to the Schwaben but having one gas cell less, it was also powered by three of the 145 horsepower Maybach engines. The Z III (LZ 12), in all important respects a copy of the LZ 9 and the DELAG airships, made its first flight on April 25, 1912, and was turned over by the Luftschiffbau to the army at Metz.

As war approached, five more airships were delivered to the Army in 1913. One of these, the Z IV (LZ 16), set out on April 3 to make a high altitude flight on its way from Friedrichshafen to Baden-Oos. The military acceptance commission was on board. Rising above the clouds the Z IV soon became wrapped in snow and was blown off course. When at last the crew brought the airship back below cloud level, the ground appeared unfamiliar. Having landed to find their bearings, they were embarrassed to find that they were near Lunéville in France. Under French guard, the Germans were obliged to disembark. They were allowed to proceed the next day, but not until the French had inspected the airship very thoroughly.[39]

Three more airships were delivered before the beginning of war in August, 1914. The whole series, from Ersatz Z II to Z IX differed from each other or from the DELAG airships only in minor details. On the army airships the cabin in the keel held a radio set and whatever bomb racks were put aboard. On August 1, 1914, the German Army had six of the Count's airships in operation and could commandeer the DELAG airships as well if the need arose.[40]

At the outset, the German Navy had been even more reluctant than the Army to procure rigid airships. The Naval Minister, Grand Admiral Alfred von Tirpitz, neither needed nor could afford them. While realizing the value

of the airship for scouting at sea, he was convinced that the early airships were too small, had too short a range, and, above all, were too slow to be of naval use. He preferred to observe progress from the sidelines.[41]

Yet, in 1910, Tirpitz had assigned a naval architect, Marine Engineer Felix Pietzker to keep abreast of airship developments. Pietzker soon became an advocate of a streamlined enlargement of the Zeppelin design fitted with six 140 horsepower engines, which could travel at 45 miles per hour.[42] The drawback was the estimated cost: 3,000,000 M. Count von Zeppelin, ever the empiricist, admitted that he was several years away from such a design.[43]

In 1911, a number of factors combined to make Tirpitz more favorably disposed to the use of airships. Public opinion (necessary for the granting of funds from the Reichstag) favored Count von Zeppelin; there was the Kaiser's growing interest; and disquieting reports of airship progress in foreign navies had become available. Thus, on April 24, 1912, Tirpitz placed an order for one of Count von Zeppelin's rigid airships. The order called for a four engine design holding nearly 883,000 cubic feet of gas, but the Count only wanted to build one like the then-current production model with three engines and a volume of slightly over 706,000 cubic feet. The craft that emerged was a compromise with three engines and a volume of

793,600 cubic feet. It was practically a replica of the Viktoria Luise. Designated as the L 1 (Luftschiff 1) and commissioned on October 17, 1912, the airship was placed in service immediately.[44] On January 16, 1913, Tirpitz set forth a five-year program for the development of a naval airship arm that included the purchase of 10 rigid airships.[45]

The first of these craft was contracted for on January 30, but construction was not begun until May. This airship was designed by Pietzker and only with great reluctance did the Luftschiffbau Zeppelin undertake its construction under the factory designation LZ 18. By inverting the keel and putting it inside the hull, Pietzker had been able to increase the diameter of the hull from 48.5 feet to 54.5 feet while retaining the same overall height, 62 feet. Thus the gas volume was increased to 953,000 cubic feet in a hull no longer than that of the L 1. The increased lift permitted the addition of a fourth Maybach engine (of 165 horsepower). The engines were mounted in two gondolas while the commander and controls were in a separate car attached directly to the hull forward of the first engine gondola.

The flaw in this design was that gas from the automatic valves on the underside of the gas cells spilled into the gangway with no place to go from there, while the engine gondolas were pulled up close beneath the hull. Pietzker,

in an attempt to further streamline the airship, made matters worse by having windscreens fitted that completely blocked the few feet between the engine gondolas and the hull, which meant that the gas from the cell valves could easily reach the engines.

Nevertheless, the design was sufficiently aesthetically pleasing to evoke congratulations from Count von Zeppelin. The airship was completed on September 9, 1913. On the very same day disaster struck the industry again. While on autumn maneuvers, the L 1 had crashed into the North Sea. Fourteen of those abroad were drowned. Despite the many wrecks, this was the first of Count von Zeppelin's airships to claim human lives, and the news was taken hard throughout Germany.[46]

Worse was yet to come. On October 17, on a trial flight, the L 2 exploded killing all aboard.[47]

Count von Zeppelin (who felt that his airships were being blamed for the naval disasters) unfortunately chose the public funeral service for the dead of the L 2 to begin a loud and heated quarrel with Tirpitz. Yet, at the insistence of the new Chief of the Naval Airship Division, Captain Peter Strasser, still another order was placed for a rigid airship--the L 3, which was to be a copy of the L 1. The L 3 was completed on May 11, 1914, and was transferred to Fuhlsbüttel bei Hamburg where it was used to complete

the training of naval crews who heretofore had used the Sachsen of the DELAG line.[48]

Henceforth, while Count von Zeppelin stayed on at Friedrichshafen, he took less and less interest in the invention that bore his name.[49] He died at Friedrichshafen on March 8, 1917.

In the six years from 1908 to 1914, the rigid airship had come from the two wrecks at Echterdingen and Manzell to the brink of success in Germany. A commercially successful airline operated three airships with another ordered. The Army had bought 12 and still flew six of them. The public, abetted by the nationalist press, thought of the airship as something uniquely German.

Yet, the rigid airship was still not a viable means of transport. There was no regular schedule (one of the essentials of contemporary commercial transport) and no need (besides catering to those who wished to fly) that could uniquely be met by the rigid airship at this stage of its development. While the rigid airship was about to undergo its test as a weapon of war, neither the German Army nor Navy had very clear ideas as to its proper use.

NOTES

1. David Lloyd George, War Memoirs of David Lloyd George, 1914-15 (Boston, n.p., 1933), pp. 31-2.

2. Hacker, Die Männer, p. 104.

3. Eckener, Graf, p. 163.

4. Luftschiffbau Zeppelin, Der Luftschiffbau Zeppelin und sein Tochtergesellschaften (Berlin: M. Schroder, n.d.).

5. Eckener, Graf, p. 164.

6. Karl von Einem, Errinerungen eines Soldaten 1853-1933 (Leipzig: K. F. Koehler, 1933), pp. 161-4.

7. See Appendix A.

8. Hacker, Die Männer, pp. 114-5.

9. For easy reference to renumbering (which followed different patterns at different times) and naming of airships, see Appendix A.

10. Hacker, Die Männer, p. 117.

11. Ibid., pp. 125-33.

12. Ernst A. Lehmann, "The Safety of the Zeppelin Airship," Mechanical Engineering, Vol. XLVIII, No. 2 (February, 1926), p. 118. See also Appendix B.

13. Colsman, Luftschiff Voraus!, p. 65.

14. Hacker, Die Männer, p. 174-9.

15. Ibid., p. 182.

16. John R. Cuneo, Winged Mars, I, The German Air Weapon, 1870-1914 (Harrisburg, Pa.: Military Service Publishers, 1942), p. 60.

17. Hacker, Die Männer, p. 185.

18. Ibid., p. 186.

19. Ibid., p. 191.

20. "Pressure altitude" is that altitude above which the pressure of the gas in the cells of the airship is sufficiently greater than that of the atmosphere to cause the automatic valves to open, permitting some to escape.

21. Einem, Errinerungen, pp. 163-4.

22. Colsman, Luftschiff Voraus!, pp. 99-102.

23. Ibid., p. 112.

24. For comparison, See Appendix A.

25. Carl Dienstbach, "The Wreck of the Deutschland," Scientific American, Vol. CIII (July 9, 1910), p. 26.

26. Deutsche Luftschiffahrts-Aktien-Gesellschaft, Passagier-Fahrten mit Zeppelin Luftschiffen (Hamburg: n.p. [DELAG], 1911), p. 6.

27. Dienstbach, "The Wreck," p. 26.

28. Ibid.

29. A bit of grim humor was provided by the helmsman, who wise-cracked, "Well, ordinarily the Teutoberg Forest lies in Deutschland, but now Deutschland (the airship) lies in the Teutoberg Forest." Quoted in Ernst A. Lehmann and Leonhard Adelt, Auf Luftpatrouille und Weltfahrt (Berlin: Volksverband der Bucherfreunde Wegweiser-Verlag, 1936, p. 156.

30. Eckener, Graf, p. 172.

31. Ibid., pp. 172-3.

32. Hugo Eckener, Im Zeppelin über Länder und Meere (Flensburg: Verlagshaus Christian Wolff, 1949), p. 30.

33. See Appendix A for dimensional data.

34. Robinson, Giants, p. 59.

35. Friedrich Heiss, _Das Zeppelin-Buch_ (Berlin: Volk und Reich Verlag, 1936), pp. 38-9.

36. Eckener, _Graf_, p. 180. Also, "The Destruction of the _Schwaben_," _Scientific American_, Vol. CVII (1912), pp. 47-8.

37. Goldbeater's skin is a thin membrane from the intestine of an ox. Up to 50,000 were used in a single gas cell. Luftschiffbau Zeppelin, _Der Luftschiffbau_.

38. Lehmann, _Auf Luftpatrouille_, p. 57.

39. _Ibid._, p. 72.

40. These were the _Z IV_ (Königsberg), _Z V_ (Posen), _Z VI_ (Cologne), _Z VII_ (Baden-Oos), _Z VIII_ (Trier), and _Z IX_ (Dresden).

41. Alfred von Tirpitz, _Memoirs_, Vol. I (New York: Dodd, Mead, and Co., 1919), pp. 181-3.

42. Germany, Militärgeschichtlichen Forschungsamt, _Die deutschen Luftstreitkräfte_, "Denkschrift des Marinebaumeisters Pietzker vom 27. Juni 1910 über die Verwendung von Luftschiffen in der Marine," document #91, pp. 199-205.

43. Colsman, _Luftschiff Voraus!_, p. 157.

44. Germany, Militärgeschichtlichen Forschungsamt, _Die deutschen Luftstreitkräfte_, "Denkschrift des Werftdepartements über die Entwicklung und Ziele der Marineluftfahrt," August 1, 1912, document #94, p. 213.

45. _Ibid._, "Denkschrift des Werftdepartements zum Immediatvortrag über die Einstellung erhöhter Mittel für die Marineluftfahrt," January 16, 1913, document #96, pp. 217-9.

46. Horst Treusch von Buttlar-Brandenfels, "Die Aufgaben der Luftschiffe im Dienste der Marine," in _Unsere Luftstreitkräfte 1914-18_, ed. by Walter von Eberhardt (Berlin: C. A. Weller, 1930), p. 107.

47. Horst Treusch von Buttlar-Brandenfels, _Zeppelins over England_, trans. by Huntley Paterson (New York: Harcourt Brace, 1932), pp. 24-5.

48. Buttlar-Brandenfels, "Die Aufgaben," in _Unsere Luftstreitkräfte_, p. 107.

49. Colsman, _Luftschiff Voraus!_, p. 181.

CHAPTER V

THE RIGID AIRSHIP IN WAR

When armed conflict engulfed Europe in 1914, Germany was the first to exploit the usefulness of the airship. Despite initial setbacks and high losses, the German Navy employed them simultaneously as strategic bombers and long-range scouting vessels. Direct naval participation in designing new models brought a steady enlargement of the rigid airship as well as dramatic improvements in its speed, lift, and range. The introduction of virtual military control and the subsequent lifting of patent restrictions enabled the Luftschiffbau Zeppelin designers to draw features from the somewhat advanced designs of the rival Schütte-Lanz Airship company.[1] Yet, by the end of the fourth year of the war, the rigid airship was all but discredited as a military weapon.

At the outset of the war, the German Army had 10 rigid airships and the Navy one;[2] but neither service had had sufficient experience with them to determine their capabilities. Moreover, the need for strategic reconnaissance by rigid airship, foreseen by Moltke in a memorandum

of April 6, 1912, hardly existed when the enemy was to be forced to surrender in a few weeks.[3] The course of the war, however, came as a surprise to everyone.

In the first few weeks of the war the Army's operational airships in the West carried out one unsuccessful raid on the fortress of Liége, as well as a daylight reconnaissance mission over the French First Army retreating from Sarrebourg.[4] Hampered by slow speed, insufficient rate of climb, and an inadequate ceiling, the Z VII and the Z VIII were shot up so badly that loss of gas forced both of them to land. On the Eastern Front, the airships based at Königsberg and Posen (the Z IV and the Z V) reconnoitered the Russian First and Second Armies advancing into East Prussia, but the Z V was riddled with machine gun fire and forced down because of gas leakage. These initial losses were a serious setback, resulting in the abandonment of daylight reconnaissance flights. As more airships became available, they were pressed into service as strategic bombers. The airship was to assume a role in land warfare never envisaged by Schlieffen.

At sea, as on land, events took their own course. The assumption behind Admiral von Ingenohl's carefully prepared plan for naval operations was also proved false. The British Royal Navy had neither the need (the submarine menace came later) to maintain a close blockade of German

ports nor the desire to divide its forces so close to Germany. In fact, the British concentrated much of their fleet on the opposite side of the North Sea from the German ports. Possessing too few reconnaissance craft to patrol the whole North Sea, the German Navy was placed at a disadvantage that Ingenohl had not foreseen. In the Battle of Heligoland Bight on August 28, 1914, the German Navy suffered its first serious losses, most of which were patrol craft. The only possible replacements available in a reasonable time were not more destroyers and cruisers but rigid airships; yet these had to be larger than those currently in use.

Fortunately for both the German Army and Navy, an improved design was already under construction when war broke out. Intended for the DELAG, this airship (the <u>LZ 26</u>) had approximately the same size and gas capacity as its immediate predecessors (880,000 cubic feet) but a number of structural innovations increased its useful lift by some 5,500 pounds. The material used for the metal skeleton was a new, stronger alloy of aluminum with small quantities of copper, manganese, and silicon. The additional strength of this duralumin permitted the elongation of each bay to some 39 feet, reducing the number of cells from 18 to 15. The heavy rubberized cloth used previously for gas cells was rejected in favor of the goldbeater's skin on cotton that had been tested in some of the DELAG craft.

The gangway was partially inside the hull, but the mistake (that had destroyed the LZ 18) of placing the gondolas close beneath it was avoided. At first left open, these gondolas were later enclosed, improving the crew's comfort and its efficiency. Two engines in the rear car drove propellers on the hull as in previous models, but the forward engine drove a propeller at the rear of its streamlined gondola. The control surfaces were simplified into horizontal and vertical fins. This airship was delivered to the Army in December, 1914, and two more (one for each service), similar except for a completely enclosed gangway, were delivered early in 1915.

While the airship was to play a role in naval warfare which the German Naval Ministry had at least hoped would be unnecessary, the Ministry at least was convinced that existing airships were too small to meet their particular needs. At a meeting at the Naval Ministry on August 5, 1914, the Luftschiffbau Zeppelin had undertaken to construct an enlarged version of the LZ 26 with a fourth engine and a gas capacity of 1,126,000 cubic feet. The first of these to be completed (the LZ 38) was turned over to the Army early in April of the following year. Altogether, until this design was superseded in 1916, 22 airships of this type were built, 12 for the Army and 10 for the Navy.[5]

Although more of the products of the Luftschiffbau Zeppelin were being delivered to the Army rather than to the Navy, the Company (as a strategic war industry) was placed under the direction of the Naval Ministry.[6] The naval construction corps brought in a large number of engineers who contributed significantly to improving the design of the rigid airship. The pencil form of the prewar airships was abandoned in favor of an aerodynamically superior tapered hull. Design for performance took precedence over the design for simplicity and ease of construction that had been the hallmark of the airships designed by Ludwig Dürr, under the direction of Count von Zeppelin. One of these naval engineers, Karl Arnstein (1887-1974), studying the loading capacity of the ring structures, developed the initial systematic method of stress analysis for rigid airship hull frames.[7] The work of these men provided increased stability at higher speeds and a stronger frame work, both prerequisites for the larger, faster airships the Navy was seeking for its North Sea patrols.

Of historical importance is the fact that there was a growing number of officers in both services who were becoming convinced that the airship was particularly suited for a role in warfare that neither Army nor Navy leaders had mentioned before hostilities had begun: namely, the bombing of enemy cities. Attacking enemy population centers, argued Deputy Chief of the Naval Staff, Rear

Admiral Paul Behncke (one of the early advocates of this form of war against civilians), would cause great panic and possibly create sufficient pressure on the enemy government to effect its withdrawal from the war.[8] In addition, the new threat against enemy cities would divert men and material from the fighting front at very little cost to Germany. Rear Admiral Philipp, the newly appointed Chief of the Naval Air Forces, became a strong advocate of raids against England and argued that the October weather would provide ideal conditions.[9] Captain Peter Strasser, the Commander of the Naval Airship Division (who wielded more influence than his rank would seem to warrant), believed so strongly in the airship as a strategic bomber that he continued to lead raids against Britain (as opposed to scouting missions) until he died when his airship was shot down on the last raid of the war. General Erich von Falkenhayn, who had succeeded Moltke as Chief of the General Staff, advocated adoption of a plan for raids of a joint army-navy airship force on Britain under Army control.[10]

Two obstacles hindered both services from implementing this idea until early in 1915: one was the lack of airships; the other was the Kaiser. Imperial consent had to be obtained to initiate the action. The order given by

Admiral Hugo von Pohl (Chief of the Naval Staff), for bombing raids to be made by naval airships on enemy cities (after French Voisin bombers had attacked Freiburg on December 4 and 19, 1914), had to be rescinded in deference to the Kaiser.[11] Influenced by the irresolute Chancellor Theobald von Bethmann-Hollweg, and his own solicitude for historical monuments and the safety of his royal cousins, the Kaiser restrained Pohl until January 7, 1915, when permission was given to proceed on a limited basis. While London itself was not to be attacked, the docks and military targets on the lower Thames and the coast could be assailed.[12]

The first raid was carried out on January 19, 1915. Three naval airships set out but only the L 3 and the L 4 actually crossed the North Sea. They succeeded in bombing the naval port of Great Yarmouth and caused some damage in the town of Kings Lynn. Both airships, however, returned to their base at Fuhlsbüttel only with difficulty. They were of the comparatively small prewar LZ 4 type, just barely capable of reaching the east coast of England with a small supply of bombs. Although the results of the raid were meager (some 20 casualties and £7400 of damage), the effect upon German morale was spectacular. This, despite the fact that the commander of the L 4, navigating by dead reckoning, had misestimated his position by some 60 miles to the north. He might easily have bombed the royal

palace at Sandringham by mistake. Moreover, Bethmann-Hollweg worried about the effects of this raid on neutrals.[13]

Of these things the German public knew nothing. What they read in the press were bombastic editorials praising the new strike against Britain. Hysteria prevailed. German children (reflecting the wishes of some parents) chanted:

> Zeppelin, fly,
> Help us in war,
> Zeppelin, fly,
> England shall be burned,
> Zeppelin, fly![14]

Further raids followed, bringing the war to British towns that had not been seriously threatened since the departure of the Spanish Armada in 1588. Under constant pressure by the armed forces, on February 12, 1915, the Kaiser relaxed his order excluding London. Henceforth, according to a highly classified order of that date, only the residential areas and the royal palaces were to be spared. The Army interpreted this to mean that all areas east of the Tower of London could be bombed, but the Kaiser balked at this and put London off limits once again. The ban was lifted in May at the insistence of the chiefs of staff. The first raid on London was carried out by Army airships on the night of May 31, 1915. Mostly ineffective, the 3,000 pounds of bombs dropped destroyed a few houses and caused 42 casualties.[15]

The last of the Kaiser's reservations about bombing London (with the exception of royal palaces and historical monuments) yielded to the arguments of the new Chief of the Naval Staff, Admiral Gustav Bächmann, in an audience on July 20, 1915. This coincided with the arrival of the first of the large airships ordered in August of the previous year. Raids began in earnest, increasing in frequency throughout the rest of 1915 and peaking in 1916 to the detriment of the "routine" scouting flights. In 1915, there had been 297 reconnaissance flights in a period of 124 days. In 1916 there were but 253 such flights on 89 days. Airships sent on bombing raids rose from 47 to 187 in the same period.

Most of the airships involved in these raids were of the LZ 38 type that had been proposed and accepted at the conference in the Naval Ministry in August, 1914. Although 197 feet of the midsection of the craft was still of uniform diameter (61.35 feet, maximum), the streamlining of the bow and the tapered stern plus the extra engine gave a maximum trial speed of nearly 60 miles per hour, an increase of nine over the previous type. Nineteen longitudinal girders, the top one being of a double triangular cross-section, connected the main ring frames at intervals of 33 feet. In addition, light intermediate rings were spaced midway between the main ones. The 16 gas cells were

supposed to be made of three layers of goldbeater's skin glued to cotton fabric for strength as well as impermeability, but, because insufficient quantities of the membranous material were available, rubberized fabric was sometimes substituted. The automatic pressure relief valves at the bottom of each cell emptied into the internal gangway and diffused upward and outward between the cells and the cotton hull, the top of which was left undoped to facilitate this.[16]

The control and engine cars were quite similar to those of the LZ 26. Instruments housed in the control car included an altimeter (based on barometric pressure), a magnetic compass (a gyro compass was too heavy), an inclinometer (to determine the angle of the ship in flight), air and gas thermometers (to determine the lift of the airship), a statascope (an indicator of the rate of climb), and a recording barograph (to help detect unfavorable trends in weather development).[17] One engine behind the control car drove a propeller at the rear of the car while, of the three engines in the car aft, two drove side propellers on the hull and the rearmost drove one at the rear of the gondola. In September, 1915, the airships of this class were fitted with new Maybach six cylinder 240 horsepower HSLu engines; however, a number of engine failures due to overheating caused the loss of at least one airship and the close escape of several more until they were rebuilt

in March, 1917, to include airscoops to provide additional cooling.[18]

These LZ 38 type airships continued in service well into 1916 (and later on the Eastern Front). Late in 1915, however, it became apparent that the British and the French (for raids were occasionally made on French cities) were developing improved methods of anti-aircraft defense. Anti-aircraft gun crews were improving in accuracy and squadrons of airplanes were being organized to attack the raiders. The Germans countered by adding two more gas cells (one 16.5 feet and the other 33 feet in length) amidships, increasing the overall length from 536 feet to 585.5 feet, which added some 1,500 feet to the operational ceiling of each airship. Yet casualties continued to mount.

The succession of Vice-Admiral Reinhard von Scheer to the command of the High Seas Fleet on January 8, 1916, brought a new element to play in the role of the rigid airship in war. Scheer not only brought aggressive leadership to the battle fleet, he also exerted influence on behalf of his friend Peter Strasser, the Commander of the Naval Airship Division. While, as a result of heavy casualties, the Army downgraded its airship service in 1916 (crossing the Western Front was considered so deadly to the rigid airships that it was forbidden after March, 1916), the

Naval Airship Division grew in importance.[19] Its raids upon Britain became larger and more frequent.

The Division also assumed greater importance in fleet operations. While poor visibility prevented the five airships sent out from playing a major role in the Battle of Jutland (May 31, 1916), two other naval airships covering Scheer's withdrawal to Heligoland Bight the next day (June 1) were able to report the location of the British forces.[20] This information, although not entirely accurate, persuaded Scheer that Jellicoe had suffered a serious defeat in the battle and was calling in reinforcements from the English Channel.[21]

The day before the inconclusive Battle of Jutland, the first of a new type of rigid airship had been delivered to the Navy at the base at Nordholz. This airship, the L 30, was the result of a departure from previous design restrictions. Originally, in March, 1915, the Naval Ministry requested designs from Luftschiffbau Zeppelin for an airship to fit in the largest hangars then in the North Sea. The best proposal was for a five engine craft with a capacity of some 1,590,000 cubic feet. Dissatisfied, the Aviation Department of the Naval Ministry rejected this design and decided on a different approach on July 22, 1915.[22] Consequently, the engineers were requested to submit a design for a six engine airship unhampered by existing

shed measurements. Meanwhile, enlargement of the old sheds and construction of new larger ones were started.

The plans were completed and construction of the new airship began in February, 1916. With a length of 649.9 feet and a diameter of 78.5 feet, the hull was completely streamlined except for a short cylindrical section amidships. Gas capacity rose to 1,949,600 cubic feet. The ring and longitudinal structure of the hull was modified only slightly so that there were 13 main longitudinals and 12 light auxiliary girders spaced between them. The 15 rings in the center of the airship were reinforced with kingpost bracing. Additional bracing to reduce the load on the transverse wire bracing of the main rings (as occurred when a cell deflated, permitting those adjacent to it to bulge into the space) was provided by an axial cable running from the bow to the stern through the center of each gas cell and fastened to each ring. Another wire ran diagonally from the top girder to the keel below in each of the 10 largest gas cells. The extra two engines were placed in small gondolas suspended amidships to port and starboard while two of the three engines in the rear car were juxtapositioned to reduce the size of the gondola. These gave the L 30 a trial speed of 62 miles per hour with a maximum of 61,600 pounds of useful load.

Various models of this airship influenced the development of rigid airships outside Germany. The fourth one

produced, the L 33, having been forced down by shellfire near the English coast, fell into the hands of the British Admiralty. By the time the crew could try to set their airship afire, so much gas had been lost that the blaze merely warped the metal structure rather than melted it. Drawings, sketches, and photographs of the skeleton provided British naval airship designers with sufficient information to build several copies, including the R 33 and the R 34.[23] A modified airship of this class, the German L 49, similarly served as the prototype for the United States Navy's airship Shenandoah.[24] One great drawback of these large airships (even with a maximum ceiling of about 13,000 feet) was that they were well within the range of airplanes being developed for use at the Front. The night-flying aircraft of the Royal Flying Corps (equipped with incendiary bullets in the late summer of 1916) accounted for two of the new airships in the fall.[25]

The use made of this new kind of war transport depended very much on the personal idiosyncracies of those who led the German armed forces. So far as the German Army was concerned, the concluding chapter in its use of the rigid airship opened with the appointment on August 29, 1916, of Generals Paul von Hindenburg and Erich Ludendorff to the command of the German Army. As part of a reorganizational move, they appointed General Ernst von Hoeppner to command all phases of army aviation. Hoeppner promptly

curtailed the activities of the army airship service in favor of large multi-engined airplanes. In June, 1917, he decided to forego the use of airships at all. Those remaining in army hangars were either turned over to the Navy or, if no longer usable, decommissioned and dismantled.[26]

Matters in the Navy (again chiefly because of personalities) took a different course. Confronted with the problem of continued high losses, Strasser opted for improving the capabilities of the airship. Although the Naval Ministry had tentatively suggested a design for a new seven or eight engine high-speed airship with an operational ceiling of 13,000 feet, Strasser realized that this would not do. The crucial need was not size and speed but height. Altitude was the only way to escape airplanes. On January 17, 1917, he proposed that the L 30 class be stripped of all nonessential extras and that a new lighter two engine after gondola be used in place of the current bulky three engine one.[27] He estimated the weight saved would enable the airships so altered to attain altitudes of 16,500 feet or more. Ten days later, at a conference with engineers of Luftschiffbau Zeppelin, Strasser put forth his ideas which were accepted for incorporation in all airships then under construction. The airships already built were to be lightened as much as possible.[28]

Of the next five airships completed by the Zeppelin Company, four embodied weight-saving modifications. The first two, the L 42 and the L 43, had the third engine removed from the stern car and did away with port side bomb releases and doors as well as all machine guns and mounts. In an altitude trial, the L 42 reached 19,700 feet. The hull frame was lightened and a streamlined twin-engine aft gondola with one stern-mounted propeller was introduced in the L 44. This type of gondola was subsequently fitted to all remaining airships. Whereas the engine gondolas amidships were streamlined in the L 46, the L 48 was fitted with a smaller, lighter control car that reduced weight an additional 2,400 pounds.[29]

On August 21, 1917, the first of a series of 10 airships with a major design change in the hull was commissioned by the Navy. This airship, the L 53,had four fewer main ring frames amidships. The remaining nine were spaced at 58.5 feet rather than 39 as before.[30] The weight saved enabled the L 53 to attain a height of 20,700 feet, but the weakening of the hull structure made this class of rigid airship incapable of withstanding full speed turns at low altitude because of the greater resistance of the denser air.[31] Consequently special instructions had to be issued to the crews to avoid such maneuvers.

Strasser's expectations that the high altitude airships would be able to raid Britain without further concern for the defending anti-aircraft guns and fighters (armed with incendiary ammunition) were almost entirely fulfilled. Only two more rigid airships were downed by British airplanes and none were lost to anti-aircraft fire. Nevertheless, the high altitude performance of these airships complicated earlier problems and introduced entirely new and unforeseen ones that reduced the frequency and effectiveness of raids. Navigation was at best a haphazard combination of dead reckoning, sighting unfamiliar landmarks when visible, and a crude, inaccurate system of radio triangulation. The new airships, even farther from the ground, were usually above layers of cloud, making them almost totally dependent on their radio direction finding equipment, which gave often quite erroneous bearings ("night effect" on radio transmission was not yet a recognized phenomenon).[32] Consequently, although an airship captain might believe he was bombing London, more often than not the bomb load was being spread across the countryside.

Furthermore, as heating equipment was both dangerous and heavy, there was none aboard these ships. The higher altitudes caused a bitter numbing frostbite. Extreme heights also posed the dual problems of oxygen starvation

and severely reduced engine power. Speeds in excess of 60 miles per hour at sea level were reduced to 45 miles per hour at 20,000 feet. On October 17, 1917, five (out of the 11 lightened airships raiding Britain) were lost in a gale.[33] The severity of the problem of power loss at high altitude had been underestimated; it now demanded solution. On November 3, 1917, the newly constructed L 58 arrived at the Naval Airship Base at Ahlhorn (in Oldenburg) with Maybach MbIVa engines, especially designed and apparently built by hand for high altitude operation.[34] The oversized cylinders and compression ratio of 6.08 to 1 gave 142 horsepower and drove the L 58 at 60 miles per hour at 19,700 feet.

There still remained the grave problem of the greater hydrogen consumption by the high altitude airships. Each base was equipped with a hydrogen generating plant, but its capacity and that of the high pressure storage tanks were limited. To maintain the purity of the hydrogen in the gas cells and lessen the chance of explosion, the cells of each ship had to be refilled to 100 per cent of capacity after each flight with a topping off each day to prevent inward diffusion of air. The expansion of the gas as an airship climbed to altitude caused much of it to be released through the automatic valves. More was lost through maneuvering. Replacing these losses required over a million cubic feet of hydrogen for each airship. As things were,

the higher the airships flew, the fewer the sorties. This was borne out by conditions at Ahlhorn where six airships drew upon a generating capacity slightly in excess of one million cubic feet per day.[35] Other bases were even less capable of meeting their own requirements. The precarious balance between supply and demand was altered unfavorably when the supply plant at the airship base at Seddin in the Baltic exploded in July, 1917, forcing Strasser to curtail some operations in the North Sea.

The crisis of the German naval rigid airship came in the summer of 1917. General Ludendorff, anxious to expand aircraft production to help offset the American entry into the war, demanded that airship production be halted to conserve aluminum and rubber.[36] Strasser, through Scheer, vehemently objected, stating that at least one airship every two months would be needed just to maintain the scouting force in the North Sea. If the raids were to be continued, one airship a month would be the minimum requirement. The conflicting claims were resolved by the Kaiser, who decided in favor of retaining the one ship every two months replacement rate.[37]

As a partial consequence of this Imperial decree, only one more advance in design was made in airships commissioned for the Navy. In December, 1917, Strasser, realizing that the insufficient power of the engines of

the airships involved in the disastrous raid the previous October was the primary cause of the losses, proposed the construction of a lengthened high speed craft with seven engines. The following April, the construction of four lengthened airships of 2,190,000 cubic foot capacity was ordered.[38] Essentially similar to the L 53 class but with nine long cells amidships instead of eight, the L 70 was almost 694 feet long. It carried seven of the Maybach MbIVa engines: one in the forward gondola, two in the rear, and four arranged in two pairs of small cars amidships. Much of the external wire bracing was eliminated with the use of thick cantilever fins rather than thin fins with hinged control surfaces aft. On its trials on July 1, 1918, the L 70 attained a height of 23,000 feet with a maximum speed of 81 miles per hour. Strasser believed this was the "final type."[39]

Later in July, 1918, Admiral Wilhelm Starke, overruling Strasser, ordered a still larger airship.[40] This one was to have six engines and a gas capacity of 2,648,350 cubic feet. Little or no work was done before a conference held at the Naval Ministry on September 7, decided to enlarge the design for this airship, increasing its gas capacity by almost 50 per cent to 3,813,400 cubic feet. It was to have 10 Maybach engines and to be almost 781 feet long. The contract was cancelled and the war

ended before this design advanced far from the drawing board.

The Armistice of November 11, 1918, brought an end to the flights of the German Naval Airship Division. By then, the driving force behind it was already dead, Captain Peter Strasser died on August 5, when the L 70 (in which he was leading what was to be the last raid on Britain) was shot down by a British De Haviland DH4. With his death the hydrogen-filled rigid airship was all but discredited as a weapon of war.

While the Allies at Versailles argued about disposal of the German airships, ex-crewmen conspired to destroy six of them.[41] The other airships were shared among the Allies: the LZ 113 and the L 72 went to France, the L 71 and the L 64 to Britain, the L 61 and the LZ 120 to Italy, the L 30 to Belgium, and the L 37 to Japan. Most of the airships were studied and then dismantled.[42] All the sheds except the three at Friedrichshafen were torn down. The building of other large German rigid airships was specifically forbidden by the Treaty of Versailles.[43]

Yet the influence of the German airship could not be effaced. Besides the introduction of sound aeronautical and engineering principles into the design and construction of increasingly large rigids, the pioneering experiments of the Naval Airship Division forecast the role of the rigid

airship in the 1920's and 1930's. (See airship development chart, next page.) An example is the flying aircraft carrier idea embodied in later American rigid airships. The technique of dropping airplanes from an airship was used with the L 35 on January 26, 1918, but was abandoned because there was no fighter with an altitude compatible with that of the airships from which they were to be released.

Another contribution of German wartime airship travel was the increased distance travelled. With the declaration of war in 1914, almost all of Germany's colonies had been occupied by various of the Allied Powers. In German East Africa, however, General Paul von Lettow-Vorbeck continued to resist. Carrying on guerrilla warfare with a handful of white troops and a varying number of native askaris trained by his men, Lettow-Vorbeck tied down forces much larger than his own and still managed to control a sizeable section of the interior upland. In May, 1917, a former colonial medical officer proposed sending a rigid airship with medical supplies to Lettow-Vorbeck. As the southernmost airship base available was at Jamboli in Bulgaria (some 3,600 miles from the intended landing point), the trip was regarded as being one way only. The Naval Minister approved the idea in principle, and a joint study by Strasser, the Colonial Office, and Luftschiffbau Zeppelin representatives confirmed its feasibility.[44]

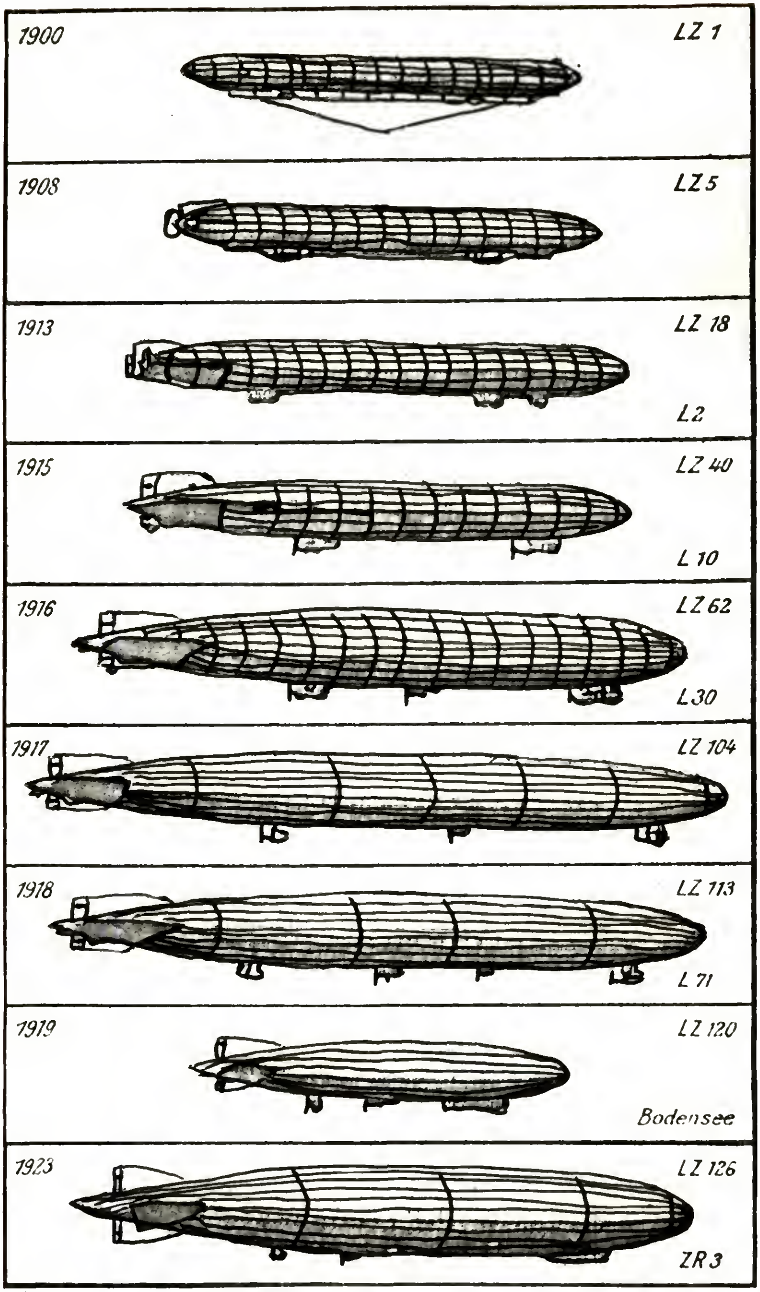

Figure 5: Comparative chart illustrating changes in the size of rigid airships, 1900-1923.

Consequently, the Navy Ministry ordered the L 57 (under construction) lengthened by two large gas cells amidships, but its inexperienced captain caused it to be wrecked and burned when he tried to bring it out of its shed with a storm brewing. The next ship nearing completion, the L 59, took its place. Loaded with some 30,332 pounds of special cargo, the L 59 lifted off for Jamboli from Staaken (near Berlin) on November 3. After two false starts, the airship left Jamboli on November 21. Lieutenant Captain Ludwig Bockholt steered his airship on a course over Asia Minor to Smyrna and thence to Africa. Except for the failure of one engine and a near miss of a hillside because of the drastic temperature variation, the flight went smoothly until early in the morning of November 23, when the airship received radioed orders to return as Lettow-Vorbeck had been driven from the anticipated receiving area and continuation of the flight would be useless.

After some discussion, it was decided to follow the order (which was genuine but issued on mistaken information as Lettow-Vorbeck's troops had not been dislodged from the highlands).[45] At 7:40 A.M. on November 25, the L 59 landed at Jamboli again. Altogether, the nonstop flight had covered 4,200 miles in 95 hours with sufficient fuel on board for another 64 hours of flight. This attempt to aid

Lettow-Vorbeck had covered distance equivalent to that from Friedrichshafen to Chicago with 22 people and over 35,000 pounds of cargo--a fact not lost on either Eckener or the Allied Powers.[46]

The four years of the First World War were momentous ones for the development of the rigid airship. The naval engineers brought into the design staff of the Luftschiffbau contributed the important element of aerodynamic hull design. Performance capability was improved through using more powerful engines and enlarging the hull to increase the gas capacity (and thus the lift). Yet militarily the airship did not meet the demands placed upon it. Whereas teaming the rigid airship with submarines against merchant shipping might have crippled Britain, the rigid airship continued to be used in reconnaissance in the North Sea where it at least provided useful information and compelled the Royal Navy to try to mask its operations. By and large, the German Naval Airship Division concentrated on bombing raids against British cities. Forced to fly at high altitudes, their effectiveness was seriously reduced.

Peculiarly important is the fact that the role of the rigid airship in naval warfare was largely dependent upon the personality of the Commander of the Naval Airship Division. Strasser's determination to attack Britain caused the designers to concentrate on modifications which

were only obtained at the expense of structural strength. The Allies were not aware that the airships they captured and copied were designed for maneuvering only above 7,000 feet. This fact was learned only by experience and by sacrifice of Allied crews.

NOTES

1. The Luftschiffbau Schütte-Lanz will be discussed in the following chapter.

2. One of the army airships was the Schütte-Lanz SL 2, which had been delivered to the army on May 12, 1914. Schütte-Lanz airships almost never found favor with the Navy primarily because of their wood hull structure.

3. Memorandum, "Chef des Generalstabes Moltke an den Kriegsministerium," November 6, 1912, reproduced in Erich Ludendorff, The General Staff and Its Problems, I, trans. by F. A. Holt (New York: E. P. Dutton & Co., n.d. [1920]), pp. 45-6.

4. There were only four, as the commandeered commercial airships were considered fit only for training.

5. The numbering system of the Navy and the Army as well as the factory designation for each airship are set forth in Appendix A.

6. Douglas H. Robinson, The Zeppelin in Combat (London: G. T. Foulis & Co., Ltd., 1966), pp. 89-90.

7. A. D. Topping, "Dr. Karl Arnstein," Buoyant Flight, the Bulletin of the Lighter-Than-Air Society, Vol. XXII, No. 3 (March - April, 1975), p. 2.

8. Memorandum, "Admiral z. S. Behncke an den Chef des Admiralstabes," August 20, 1914, cited in Hugo von Pohl, Aus Aufzeichnungen und Briefen während der Kriegszeit (Berlin: K. Siegismund, n.d. [1920]), p. 36.

9. Letter, "Konteradmiral z. S. Philipp an den Chef des Admiralstabes," October 2, 1914, cited in Ibid., p. 38.

10. Memorandum, "Kriegsminister Falkenhayn an den Chef des Admiralstabes," November 9, 1914, cited in Ibid., p. 39.

11. Letter, "Chef des Marinekabinetts an den Kommandeur des Hochseeflotte," January 13, 1915, in Georg von Müller, The Kaiser and His Court, ed. by Walter Gorlitz, trans. by Mervyn Savill (London: Macdonald & Co., 1961), p. 55.

12. *Ibid.*

13. *Ibid.*, p. 54.

14. Adolf Saager, *Zeppelin* (Stuttgart: Verlag Robert Lutz, 1915), p. 214.

15. Many of the raid results are discussed in the reports of the German naval attachés in Sweden and the Netherlands. For example, "Zeppelinangriffe und ihre Wirkung, an den Staatssekretär des Reichsmarineamts," Report No. 383, National Archives, "Tambach Archives," (Kriegsarchiv der Marine), microfilm roll no. T1022/538, PG 69134.

16. Although vertical shafts between cells for the rapid evacuation of the released gas were standard practice in the Schütte-Lanz airships, they were not incorporated into the Zeppelin design until the *LZ 78* (*L 34*) was built in the late summer of 1916.

17. These were to remain the basic instruments aboard the airship throughout its development although others (mainly bomb-sights or scientific instruments) were added for specific purposes.

18. "Tagesbefehl des Befehlshabers der Marine-Luftfahr-Abteilungen, Tagesbefehl #45, March 19, 1917," National Archives, "Tambach Archives" (Kriegsarchiv der Marine), microfilm roll no. T1022/940, PG 76883.

19. Reinhard von Scheer, *Germany's High Seas Fleet in the World War* (New York: Peter Smith, 1934), pp. 210-2.

20. The erroneous report from *L 24* that British warships were in Jammer Bay on the Danish coast was not questioned as Scheer believed that was where they should be, but the accurate report from *L 11* was checked and rechecked before Scheer concluded that the capital ships reported off Terschelling were reinforcements from the Channel.

21. The actual role of airships in the Battle of Jutland contrasts strongly with the widespread belief after the war that airships had "saved the Germans at Jutland." The future of postwar airship development depended, of course, on what was believed rather than what actually occurred.

22. Thus continuing the established policy of achieving better performance through larger size. "Oberbefehl der Marine-Luftfahr-Abteilungen, Berichten, Admiralstab 'A'," National Archives, "Tambach Archives" (Kriegsarchiv der Marine), microfilm roll no. T1022/939, PG 76850.

23. The British airship program will be discussed in the next chapter.

24. The L 49 was a high altitude airship stripped of all non-essentials and with a lightened frame. The United States Navy airship program will be discussed in a later chapter.

25. Archibald Whitehouse, The Zeppelin Fighters (London: Robert Hale, 1966), pp. 145-6, 149, 181.

26. Walter Gladisch, Der Krieg in der Nordsee, Vol. VI (Berlin: E. S. Mittler u. Sohn, 1937), p. 258.

27. Memorandum, Strasser to Starke, January 17, 1917, as cited in Robinson, The Zeppelin, pp. 205-6.

28. Kriegstagebuch des S. M. Luftschiff "L 40," January 25, 1917; January 28, 1917; February 8, 1917, National Archives, "Tambach Archives" (Kriegsarchiv der Marine), microfilm roll no. T1022/395, PG 63655.

29. Kriegstagebuch des Kommandanten des Marine-Luftschiffes "L 48," National Archives, "Tambach Archives" (Kriegsarchiv der Marine), microfilm roll no. T1022/330, PG 63663.

30. The design of this class was directly the result of the work of Dr. Arnstein.

31. Kriegstagebuch S. M. Luftschiff L 53, September 25, 1917, National Archives, "Tambach Archives" (Kriegsarchiv der Marine), microfilm roll no. T1022/428, PG 63668.

32. The system used until 1918 was an "active" one: that is, each airship would send signals which were received at the land stations. The direction received from, often distorted by atmospheric conditions, would then be relayed back to the airship. This was replaced by a "passive" one in 1918 whereby the stations would broadcast and the airship crew could then plot its position from the incoming signals.

33. "Oberbefehl der Marine-Luftfahr-Abteilungen," microfilm roll no. T1022/939, PG 76850.

34. Kriegstagebuch des Marine Luftschiffes "L 59," November 3, 1917, National Archives, "Tambach Archives" (Kriegsarchiv der Marine), microfilm roll no. T1022/429, PG 63672.

35. Zwei deutsche Luftschiffhäfen des Weltkrieges, Ahlhorn u. Wildeshausen, ed. by Fritz Strahlmann (Oldenburg: Oldenburger Verlagshaus, 1926), p. 58.

36. Scheer, Germany's High Seas Fleet, p. 210.

37. Scheer contradicts this, stating that the replacement rate decided upon was one a month. Ibid., p. 211.

38. Kriegstagebuch Marine-Luftschiff L 70, July 1, 1918, National Archives, "Tambach Archives" (Kriegsarchiv der Marine), microfilm roll no. T1022/429, PG 63680.

39. As recalled by Admiral Starke, cited in Robinson, The Zeppelin, p. 327.

40. Lehmann, Auf Luftpatrouille, p. 211.

41. The reasons behind their actions are a subject of debate. Most authorities agree that the men wished to keep them from the Allies. but one of the conspirators, a machinist's mate and flight crew member who was willing to talk, stated that it was to prevent them from falling into the hands of the leftist radicals.

42. L 72, renamed the Dixmude, was the only notable exception.

43. United States, Department of State, The Treaty of Versailles and After: Annotations of the Text of the Treaty (Washington: United States Government Printing Office, 1947), p. 353.

44. Lehmann, Auf Luftpatrouille, p. 196.

45. The information available suggests that the misinformation regarding the situation of Lettow-Vorbeck's forces was intended to convince them to recall the airship.

46. The exceedingly great range of the rigid airship was a prime factor of interest in its development after the War.

CHAPTER VI

COMPETITORS AND COPIERS

Germany

Hitherto we have directed attention to the development of the rigid airship as it occurred under the guidance of Count von Zeppelin and the staff of the Luftschiffbau Zeppelin. Although this company provided the main impetus to rigid airship construction, development, and usage, it was not the only company to do so within the prewar Reich. Mention has already been made of the small non-rigid airships built by Major Gross and those constructed by the company of August Parseval. A third company, Luftschiffbau Schütte-Lanz, built rigid airships that were in some ways technologically superior to those constructed by the Zeppelin works.

The founder and chief designer of this company was Johann Schütte, an instructor of theoretical naval architecture at a technical school in Danzig. The widespread newspaper coverage attending the flight of the _LZ 4_ that ended with the conflagration at Echterdingen in 1908 (p. 82) caught his attention. He was prompted to send

a letter to Count von Zeppelin suggesting several improvements that might be made in future airships, such as doubling the outer cover, locating the gangway within the hull, and connecting the engines to the propellers with a direct drive system.[1] Count von Zeppelin acknowledged the letter but ignored the advice it contained. Undismayed, Schütte proceeded to analyze the requirements for designing an efficient rigid airship. His work eventually yielded five major criteria: a) special calculations or calculating methods for strength and stress; b) lightweight materials subjected to thorough strength analysis and adaptable to the construction of a rigid framework; c) a favorable shape for a body moving through the air based on previous studies of the motion of bodies in water; d) suitable arrangement of the stabilizing and steering surfaces; and e) in his mathematical terminology, the correlation of all thrust propulsive forces with the direction of the resultant of the resistant forces.[2]

Unlike Zeppelin's earlier unsuccessful attempts to recruit private capital, Schütte secured the backing of two wealthy Mannheim industrialists, Karl Lanz and August Röchling, who put 350,000 M. into the capitalization of the Luftschiffbau Schütte-Lanz on April 22, 1909. The company's construction shed was begun immediately in the suburb of Mannheim-Rheinau and work on the first airship commenced on the completion of this shed a few weeks later.[3]

This airship (to be designated the SL 1) took two years to complete because practical implementation of Schütte's theoretical design sometimes proved impossible and modifications had to be made. Originally designed to have a volume of just under half a million cubic feet, the SL 1 in its final form had a length of 432 feet, a maximum diameter of almost 60.5 feet, and a volume of 734,500 cubic feet, about 50,000 cubic feet more than the contemporary LZ 7. The design of the framework of the hull necessitated extra expense and construction time. The longitudinals (which in the Zeppelin airships were parallel to the central axis) were arranged in helical spirals that crossed each other in a diamond pattern. As Schütte believed there were theoretical advantages in having only a rigid frame around the gasbags, the only transverse frames were temporary ones that served as forms while helical girders were added to compensate. Despite these precautions, the flight crews were severely frightened by the undulating motion of the SL 1 when airborne.[4]

The flexibility of the framework was caused not only by its form but also by Schütte's choice of structural material, plywood. The type he selected was aspen, sliced in thin sheets, three or more of which were held together by casein glue. Lacquer and paraffin wax waterproofing were insufficient to prevent moisture from softening the glue, which was not of homogeneous quality. Girder

strength could be reduced by 50 per cent by absorption of moisture from the atmosphere.[5]

Originally, Schütte planned nine spherical gas cells separated by eight doughnut-shaped ones, but the need to reduce weight induced Schütte to substitute cylindrical cells provided by the Riedinger firm supplying Count von Zeppelin. The wires (added after the need for bracing was realized) were strung through these cells, providing points for possible leakage. Access to these gas cells was provided by ladders from the gondolas, but unlike the Count's airships there was no real passageway from one end of the airship to the other. As with the tapered, streamlined hull, the shape of the gondolas was as simple as possible. The bow of the forward one was enclosed in glass to provide full vision for the pilot. The 240 horsepower eight cylinder Mercedes-Daimler engine in each gondola drove a single large reversible three-bladed propeller through a gear reduction system. Because Schütte believed that less damage would occur on landing if there were no rigid connection between the hull and the gondolas, they were suspended by wires.

As with Zeppelin's airships, the problem of control was solved by empiric experimentation. Control surfaces on the SL 1 evolved through three stages. The initial arrangement consisted of a single upper vertical fin aft

with a large rudder independently mounted behind it. Another small box rudder was mounted behind the rear gondola. Elevators were hinged to the trailing edges of a pair of horizontal fins. Another set of elevators was mounted beneath the bow. In May, 1912, this arrangement underwent modification: the fins aft were redesigned, triple rudders were hung beneath the horizontal fins, small elevators were placed under these, and the bow elevators and the box rudders behind the second gondola were removed. This system did not please Schütte, who, in the fall of 1912, changed it a second time. The fin configuration was reduced to a simple cruciform with elevators and rudders hinged from the trailing edges.

After two years of construction (the first test flight of the SL 1 was on October 17, 1911) and another year of tests and modifications (at a total expenditure of 2,000,000 M.), the Schütte-Lanz firm was still without a buyer. The guarantee of purchase for the SL 1 from the German Army, its primary potential customer, was still unconfirmed. However, in December, 1912, General Moriz von Lynckner (1853-1932), the Inspector General of Military Transport, recommended the acceptance of the SL 1. He felt that the Luftschiffbau Schütte-Lanz provided both technical competition and a balance to the *de facto* monopoly of the Zeppelin company. Lynckner's arguments

persuaded the War Minister, and the purchase was approved for the sum of 550,000 M.[6] The reluctance of Karl Lanz to invest more funds in the corporation led to further negotiations with the Army, and on April 24, 1913, a contract was drawn up formalizing future agreements and, as with Zeppelin, preventing Schütte-Lanz from selling its products abroad.[7]

In response to an order placed by the Army at the end of June, 1913, for a second airship, Schütte altered his method of construction for the hull, conforming to the Zeppelin practice with transverse rings and longitudinal girders because he believed that the friction produced by the diamond grill pattern on the skin of the hull of the <u>SL 1</u> was responsible for its somewhat disappointing speed (44.5 miles per hour). Except for enlargement and minor modifications, all Schütte-Lanz airships completed before the end of the war were similar in design to this new airship, the <u>SL 2</u>. A triangular keel was fully enclosed in the hull, which was fully streamlined with a length of 474 feet, a diameter of 59.8 feet, and a volume of nearly 862,000 cubic feet. The valves (automatic and manual) on the 15 gas cells emptied into eight cloth chimneys which carried the gas to the top and out of the airship. At the stern were cruciform fins with elevators and rudders hinged from the trailing edges. The <u>SL 2</u> had five separate

gondolas. The control car was fully enclosed and attached directly beneath the hull well forward. One of the engine cars was suspended on either side of the hull amidships. The forward car was located behind and slightly below the control gondola while the rear one was in line aft. In contrast to the 45.5 miles per hour provided by the three engines of the contemporary LZ 22, the four 185 horsepower Maybach engines gave the SL 2 a top speed on its trial flight on February 28, 1914, of almost 55 miles per hour. After an additional gas cell was added amidships in 1915 and 210 horsepower engines supplanted the original ones, the maximum speed was increased slightly to 55.5 miles per hour.

In October, 1913, Schütte offered Admiral von Tirpitz a design for an airship of sufficient size to meet or exceed the naval requirements that Count von Zeppelin had refused to consider. Despite the merits of the design and its initially favorable reception at the Naval Ministry, Tirpitz opted for the smaller Zeppelin airship. Schütte's attempt to use his friendship with Admiral Georg von Müller, the head of the naval cabinet, to influence the Kaiser, had irritated the Grand Admiral.[8]

When war came in August, 1914, it found the Luftschiffbau Schütte-Lanz unprepared. The construction shed was being enlarged; many employees had been laid off; others

had gone to the Army. Brought under direct government control, the Company's patented features of the SL 2 were at once made available to the Luftschiffbau Zeppelin.

While many of the ideas incorporated in his SL 2 were eventually absorbed into the Zeppelin design, Schütte did not adopt the metallic skeletal structure that was the main advantage of contemporary Zeppelin airships. With Army backing (the Navy was critical), the Schütte-Lanz firm continued to use wood until the Army's airship service was dissolved in 1917. Thenceforth, the Navy refused to accept any more wooden framed airships. Even when forced to use aluminum, Schütte refused to copy the Zeppelin practice of using stamped triangular girders. The Armistice finally put a stop to all work on the aluminum airship begun the previous June. In 1919 the Allied representatives at Versailles ordered the SL 22 dismantled and various parts of its structure distributed among the victors.[9] In 1921 the Interallied Control Commission (enforcing the Versailles ban on German airship construction) also ordered the destruction of the construction sheds of the Luftschiffbau Schütte-Lanz. The company made no further attempts to build rigid airships in Germany. In 1922, having tried to keep its design staff together in the hope of one day building transatlantic airships, it settled for the less spectacular activity of manufacturing

plywood products using the technique Schütte had developed for airships.[10]

Britain

With few exceptions, there was little rigid airship development outside Germany until World War I. One of the exceptions was Great Britain, where naval interest in a large rigid airship as a scout for the fleet manifested itself in a proposal made by Captain Reginald Bacon (1863-1947) to Admiral Sir John Fisher (1841-1920, the First Sea Lord) on July 21, 1908. Bacon proposed that a Naval Air Assistant be appointed to the Admiralty and that an order be placed with the Vickers armament firm for an experimental prototype of such an airship.[11] Although comparatively little news of the first flights and potentialities of Count von Zeppelin's airships had been reported (on July 21, 1908, the test flight of the LZ 4 was still two weeks away), Fisher took an immediate interest in Bacon's suggestion. Bacon and others from the Admiralty conferred with a Vickers design team headed by design engineer Charles Robertson. Fisher, meanwhile, obtained the approval of the Treasury and the Committee of Imperial Defence.[12] The British contract was let on May 7, 1909.

The subsequent British developments cast interesting light on the comparative procedure by means of which rigid airships were first produced in Germany and Britain. In Germany (usually considered as one of the prime examples of state-directed technological development) the rigid airship came into being as the result of the will and inspiration of a private citizen. Count von Zeppelin created his own company and hired technicians to meet the engineering challenge he envisaged. Moreover, it was only after the Luftschiffbau Zeppelin was financially secure that the German defense forces (first the Army and then the Navy) showed any interest. And what support they did give was given grudgingly and hesitatingly. Only when the German public intervened--moved by national pride--was the lack of money overcome.

In Britain the pattern of events was almost the exact opposite. The idea of a rigid airship was initiated within the Royal Navy, was promoted from the start by the dynamic First Sea Lord (and accepted by the Committee of Imperial Defence), and was then contracted out on a cost-plus basis to an already established engineering firm (Vickers) for execution. It was only then that Vickers hired the design engineer whose name was to become associated with airships in Britain: Barnes Wallis (b. 1887). Moreover because most rigid airship development in Britain was planned by

and directed from the Admiralty during wartime, the expenses involved were not a significant factor until the First World War ended (£35,000 was budgeted for the development of the first airship).

For this money the Wallis group undertook to build an airship able to maintain 40 knots at a maximum altitude of at least 1,500 feet for 24 hours. Radio equipment was to be provided. There was to be accommodation for a crew of 20. The airship should be able to moor to a mast or land on either water or land.[13] These were ambitious aims, especially when one remembers that the only previously "successful" rigid airship was that of Count von Zeppelin, which had crashed at Echterdingen the previous August (1908). Subsequent British developments provide eloquent testimony of the difficulties faced by those who sought to pioneer in aviation technology. Trial and error, with emphasis upon error, seems to have been as true of the British as the Germans.

As the airship was required to land on and take off from water, Vickers chose to erect their construction shed on piles in the Cavendish Dock at Barrow, completing it in June, 1910. Construction of the airship itself began immediately but was delayed by inexperience. The hull had nearly the same dimensions as those of its contemporary, the DELAG Deutschland (p. 101), as it measured 512 feet

long and 48 feet in diameter: its skeletal structure consisted of 12 longitudinal girders and 40 transverse rings spaced 12.5 feet apart. Some of these rings (at least every third one and in the areas thought to bear the greatest strain, every second one or every one) had radial bracing. The spacing of these rings determined the length of the gas cells: three were 12.5 feet long, five were 25 feet long, and nine were 37.5 feet long. They were of rubberized fabric as the British Army airship service had found that the type of goldbeater's skin used in their kite balloons became brittle.[14]

After surveying the available materials, Vickers decided that the girders and rings should be made of the aluminum-copper alloy duralumin, a material not adopted by the Zeppelin works until 1914. Although this alloy had greater resistance to stress than aluminum, the shape of the girders (again the I beam formed from two U-shaped channels) precluded the construction of a strong hull.[15] Duralumin bracing wires repeatedly snapped under tension until they were replaced by some steel ones. Except that the bow was rounded instead of tapered, the shape of the hull resembled that of the contemporary Zeppelin airships with a long parallel section amidships and a tapered stern. A triangular keel connected both gondolas beneath the hull. In the center, it bulged to accommodate the cabin for the radio equipment.

The open gondolas were made of mahogany so that they would float on water. Each contained a 180 horsepower eight cylinder Wolseley engine weighing some 1,800 pounds. These units were 50 per cent more powerful than those of the Deutschland. Although there were only two of them, they were heavier than the three of the Deutschland. The forward gondola engine drove two propellers on outriggers, but unlike the LZ 4 the engine aft drove one mounted at the rear of the car. Compared with what had preceded it, the British airship had a plethora of control surfaces: cruciform horizontal and vertical tail fins were appended with quadruple box rudders and triple box elevators on their trailing edges; large triple elevators were also located near the bow and small triple rudders hung aft of the rear control car. Rather than hinging these control surfaces as was the German practice, the British pivoted them in the center.[16]

The principal problem with Britain's Mayfly (with emphasis on the first syllable), as the airship came to be popularly known, was that it was too heavy; as always, the British made things to last (their first railroads, it will be remembered, were ballasted to a depth of 14 feet). The initial inflation of the airship's cells was completed on May 21, 1911. However, with 95 per cent full cells (under standard conditions) the lift was 44,050

pounds, whereas the weight of the airship when empty was 43,870 pounds. The added weight is to be explained partly by the unnecessarily complicated and heavy piping, tanks, and other equipment for gasoline, water, and compressed air. Also, the water recovery system mounted aboard to condense moisture from the engine exhausts to help keep the trim of the airship (despite the consumption of fuel) weighed about 1,000 pounds. Although too heavy to be practical, the Mayfly showed considerable technical initiative and insight.[17] The same could not be said for the unnecessary and heavy capstan (225 pounds) and hawsers (650 pounds) aboard.

It soon became evident to those concerned that the weight of the nautical gear would have to be reduced; the quantity of fuel and the number of crew would similarly have to be reduced. Because the size of the shed precluded lengthening the airship by adding cells amidships, extra lift could not be added; weight had to be removed. A start was made by removing the water recovery system. The metal fuel tanks and piping were then replaced by cloth ones. The two propellers on outriggers were also replaced by a single one mounted at the rear of the forward gondola. While some of the nautical gear was eliminated, items such as hawsers and a 64-pound anchor were retained. Finally, the forward set of elevators was discarded. Alas, the lift gained by these measures proved to be insufficient.

There remained only one possible source of further weight reduction: the hull frame. In the belief that the rings and girders could withstand the strains and stresses by themselves, the heavy keel was removed. Without this stiffening brace, the hull sagged at each end and arched in the center (as had that of the LZ 1). The Mayfly, it was calculated, now had a disposable lift of some 7,190 pounds.

On September 24, 1911, the modified airship was brought out of its shed. Although little agreement exists on the exact cause (some maintain a sudden squall came up while others claim the mechanical handling gear produced too much strain), the hull parted at the top just forward of the rear gondola. As the two sections continued to separate, a jackstay along the top of the hull ripped out successive rings. Although the wreck of H.M.A. No. 1 was restored (with much difficulty) to its hangar, the damage done in removing the keel to save weight was irreparable.

The Court of Inquiry, besides finding that the Mayfly was structurally weak, gave an unfavorable report on the whole project, regarding it as unnecessary and wasteful.[18] The tone of the proceedings of the Court was set by its president, Rear Admiral Doveton Sturdee, who, when examining the wreck, voiced his contempt for the Mayfly with the phrase, "the work of an idiot!" Meanwhile, Fisher had been replaced as First Sea Lord by Admiral Sir Arthur Wilson.

Both he and Winston Churchill, the new First Lord of the Admiralty, had more to worry about than how to finance these first attempts to launch the rigid airship. Naturally, they declined to authorize further experiments.[19]

Yet, the problem of the airship would not go away. Reports of the success of the German DELAG airships (particularly the Schwaben) continued to arrive at the Admiralty. The course of German developments was also followed by a system of espionage that seems ludicrously crude by contemporary standards. Travelling incognito, Admiral Sir John Jellicoe (1859-1935), the Controller of the Navy, took an excursion flight on board the Schwaben on November 15, 1911. Six months later, Murray Sueter and Mervyn O'Gorman, then superintendent of the Royal Aircraft Factory at Farnborough, were sent disguised as Americans to France, Germany, and Austria to obtain more information. After a five and a half hour flight in the Viktoria Luise on July 9, 1912, they reported to the Committee of Imperial Defence that

> In favorable weather the German airships can already be employed for reconnaissance over vast areas of the North Sea, and one airship, owing to the extensive view from high altitudes under favorable weather conditions, is able to accomplish the work of a large number of scouting cruisers. It is difficult to exaggerate the value of this advantage to Germany. By a systematic and regular patrol of the approaches to the coast, it will be possible in fair weather for German airships to discover the approach of an enemy and to give timely warning of the attack.[20]

The impact of this report was underscored by rumors that the L 1 of the German Navy, on a test flight with Count von Zeppelin in command, had flown over Sheerness during the night of October 14, 1912. Although the rumor proved wrong, the flight was not beyond the capability of the German craft, which lent the report credibility.

Gradually, the British were forced to have second thoughts about the airship. The outcome was a recommendation from the Committee of Imperial Defence (in the opening months of 1913) that the Admiralty should procure a rigid airship from a British firm as a prototype naval scout and training vessel. Although the order was not formally placed with Vickers (builder of the earlier ill-fated Mayfly) until June 10, the company had reassembled its design team in April. Shortly thereafter this group was given access to the plans of the German Army Z IV that had been drawn up and passed to them by the French after the forced landing of the German airship near Lunéville on April 3, 1913. The design of the new H.M.A. No. 9 followed the plans of the Z IV very closely.

Yet, despite German pressures and the availability of German technical information, British progress was slow. The dimensions of the airship (526 feet in length and 53 feet in diameter) precluded the use of the Cavendish Dock shed; consequently, a new larger one had to be erected on Walney Island near Barrow. There were also the usual changes in design that delayed construction. Three further

months were lost when the Admiralty cancelled the order on March 12, 1915, on the grounds that the war would be over before the airship was complete.[21] Although construction of the hull was begun in the autumn of 1915, the first trial flight was not held until November 27, 1916.

When completed, the airship resembled the German Z IV with the exception that the gas volume was increased to 890,000 cubic feet and there were light rings at intervals of 10 feet between the main transverse rings, which were spaced at 30 feet. Also unlike the three-engined Z IV, H.M.A. No. 9 had two enclosed gondolas each of which housed two 180 horsepower Wolseley Maybach engines that drove propellers that could be swiveled to provide directional thrust.[22]

The original contract with the Admiralty specified a minimum disposable lift of some 11,000 pounds, a ceiling of 2,000 feet, and a maximum speed of 45 miles per hour.[23] Although the disposable lift requirement was lowered to less than 7,000 pounds when armaments were added, the initial test flight on November 27, 1916, revealed that the airship had only 4,700 pounds of disposable lift. In these circumstances, the Admiralty declined to take delivery of the airship. When a Maybach HSLu 240 horsepower engine taken from the German L 33 (which was wrecked in England in September 1916) was used to replace the

Wolseleys in the rear gondola, the useful lift was increased to 8,500 pounds, and the airship was accepted on April 4, 1917. Its poor performance and inadequate lift (a contemporary German naval airship had 74,000 pounds of lift) condemned the No. 9 to a short life as a training and testing craft.[24] In June, 1918, it was dismantled after suffering considerable damage while testing a mooring system at the airship station at Pulham in Norfolk. Obviously, in this field, however stumbling the German efforts might seem, German technology was superior to the British.

Four other airships based on an improved No. 9 design were begun by the British in 1915. Their dimensions were similar to the airships being produced at the Zeppelin works in 1915 (p. 118): length, 535 feet; diameter, 53 feet; gas volume, 940,000 cubic feet in 18 cells. Control surfaces were elevators and rudders hinged to the trailing surfaces of the tail fins. Of the three gondolas, those forward and aft each contained a 250 horsepower Rolls Royce engine driving two swiveling propellers. The amidships gondola held two such engines driving two fixed propellers. Again, as with the No. 9, the engines were more powerful than those in contemporary Zeppelin airships (210 horsepower) but much heavier. The machinery was some 4,000 pounds overweight. Only by modifying the equipment carried aboard and replacing the rear gondolas with

gondolas from the L 33 was the disposable lift increased to approximately 13,000 pounds. Vickers built the No. 23 at Walney Island; the No. 24 was built by Beardmore at Inchinnan on the Clyde; Armstrong-Whitworth constructed the No. 25 at Selby in Yorkshire. The fourth aircraft of this class, the R 26, was ordered from Vickers in January, 1916.[25] Although the four airships matched the size and performance of 1915 Zeppelin airships, they were hopelessly inadequate by the time the first was completed in September, 1917. All except the No. 25 (which was built in such a way that the fore and aft gas bags surged while in flight, which made the airship unstable statically) were used in much the same capacity as was the No. 9, as trainers and testing vehicles. All were scrapped in 1919. Perhaps because they were forced to imitate the Germans, the British never seem to have made a maximum effort. Ships on water: yes; ships in the sky: no. It is possible, of course, that British reluctance to be involved with airships in the postwar period might also stem from wartime revulsion.

Meanwhile, in June, 1916, at which time the No. 23 class airships were still under construction, the Admiralty approved construction of four airships (the R 27-30) of a modified design, the 23X class. These airships, which were to be completed by mid-1917, differed from those of the No. 23 class in only one important respect: the keel

was omitted. This interesting departure from the Zeppelin design eliminated three tons of weight; yet such were the improvements in the design and bracing of the hull structure that the removal of the keel did not weaken it significantly: in this, the last class to be undertaken before the technology of the German "height-climbers" became available through the capture of the L 33, the keel had become superfluous. The result was the first really practicable craft built by British airship constructors. In 1917, however, the Admiralty decided to concentrate on copying the German L 33 design and cancelled two of these (the R 28 and the R 30). Of the other two, the R 27 was built by Beardmore and commissioned on June 29, 1918. Based at Howden, this airship completed nearly 90 hours in the air before a hangar fire (caused by an American naval crew working on a small non-rigid) consumed it and three other blimps as well on August 16, 1918.[26] The R 29 was an Armstrong-Whitworth airship that was commissioned on June 20, 1918. Its disposable lift was almost 19,400 pounds. In 1918 and 1919 it flew a total of almost 437 hours on anti-submarine patrol and convoy duty.

In May, 1916 (even before the 23X class was approved), another source of German airship technology had become available to the British in the guise of a defector. Early in 1916, a Swiss by the name of Hermann Müller arrived in England. He claimed to have been an employee on the

engineering staff of the Schütte-Lanz firm, but in fact had been the manager of the girder construction shop. After a thorough interrogation at the Admiralty, he was employed by the Admiralty's airship design department building airships with hull frames of wood girders, replicas of the Schütte-Lanz craft. British airships designed and built with Müller's technical advice (the R 31 and the R 32) were near duplicates of the SL 7.[27] Virtually the only significant difference in hulls between the British airships and their Schütte-Lanz prototype (which was an enlarged version of the SL 2 [pp. 153-4]) was the length (being some 614.7 feet long as opposed to the 534.5 feet of the SL 7) and hence the number of frames, gas cells, and gas volume (1,500,000 cubic feet to 1,204,000 cubic feet). The R 31 had six individual engine gondolas, four of which were mounted underneath in pairs forward and aft while the other two were placed well up on the hull on both sides amidships. Each car contained a Rolls Royce 250 horsepower engine that powered a propeller mounted aft of the gondola. There was but one engine car aft on the R 32, which was otherwise identical in gondola and engine arrangement. On their trials, the R 31 made 70 miles per hour while the R 32, with one engine less, made 65 miles per hour. The control cabin was built up beneath and against the hull in a streamlined shape, as had been Schütte-Lanz practice since the SL 2. The R 31 made its

first flight in August, 1918. On another trial flight on October 16, the port bracing of the upper fin gave way, forcing the airship to return to its shed at Cardington (where it had been built by Short Brothers, Ltd.) with the top fin and rudder folded over to starboard. Commissioned on November 6, the R 31 weighed off for its duty station at East Fortune. The moist atmosphere at Cardington had taken its toll, however, and breaking girders forced an emergency landing at Howden where the airship was placed in the remnant of the shed that had burned with the R 27. When examined a few months later, the R 31 was found to have rotted and come unglued beyond repair.[28] It was dismantled in February, 1919, having only been in the air a little less than nine hours.

The R 32 was not commissioned until September 3, 1919. Then it was used for some full scale tests for the National Physical Laboratory to develop systems of measurement and a set of working figures for a study of bending and dynamic stresses.[29] Meanwhile, however, the British had agreed to sell the United States a rigid airship and train an American crew in its handling (p. 199), and the tests were left unfinished while the R 32 was pressed into training service. The tests, however, were never completed. In April, 1921, as part of an austerity program, the gas cells of the R 32 were deliberately inflated beyond the capacity limit, and the wreck was then dismantled and scrapped.

The subsequent building of Britain's R 33 and R 34 owes much to two incidents. The first was the Battle of Jutland (May 31-June 1, 1916). Although the German airships had not been able to sortie on May 31 because of inclement weather, the British did not realize this. Instead, because the L 11 had been seen observing elements of the British Grand Fleet the following morning, they assumed that the airship was responsible for Scheer's elusion of the main part of the Grand Fleet. Additional credence was given by the airship activity during the Sunderland Operation of August 19, 1916. Wrote Admiral Jellicoe after the war:

> From 8.28 onwards Zeppelins were frequently in sight from both the Battle Fleet and the Battle Cruiser Fleet, and were fired at, but they kept at too long a range for the fire to be effective. The Galatea sighted the first at 8.28 a.m., and the second was seen by the Battle Fleet at 9.55 a.m.; at 10 a.m. Commodore Tyrwhitt, who was at sea with the Harwich Force, reported himself in position Lat. 52.50 N., Long 3.38 E., and also being followed by a Zeppelin. He stated later that his force was shadowed by airships during the whole period of daylight on the 19th. Reports were also received from the patrol trawler Ramexo that she had two Zeppelins in sight in Lat. 57 N., Long. 1 E. It was evident that a very large force of airships was out. A total of at least 10 was identified by our directional wireless stations and they appeared to stretch right across the North Sea.[30]

The second incident was the technical information gleaned from the German L 33, which was brought down near Little Wigborough on September 24, 1916. The Admiralty, recognizing that the German L 33 was far in advance of any

airship they had under construction or planned, decided the following November to order two copies of it, the R 33 from Beardmore and the R 34 from the Armstrong-Whitworth works. In January, 1917, three more were ordered (the R 35, the R 36, and the R 37) from Armstrong-Whitworth, Beardmore, and the Short Brothers Works. As there was construction of the previously ordered No. 24 going on at its hangar at Inchinnan, Beardmore (and Armstrong-Whitworth, working on the No. 25) delayed beginning these airships until December, 1917. More information about the German "height-climbers" became available after the L 49 was captured basically intact in France in late October, 1917.[31] Consequently, the R 33 and the R 34 incorporated the streamlined rear twin-engine gondola that was one of the features of the later German high altitude airships. The engines were 250 horsepower V-12 Sunbeam Maoris, especially designed for use in airships but not as reliable as the Maybachs. Basically, however, the dimensions of the hulls of the R 33 and the R 34 followed those of the L 33.

While work on the two airships was slowed down by the Armistice, the Beardmore firm completed the R 33 and it made its first flight on March 6, 1919. As with most of the airships completed before it, the cessation of hostilities had removed the raison d'être of the existence of the R 33. Government expenditures being reduced, the Admiralty found

itself in financial difficulties. The Navy's solution to its shortage of funds was to turn the airship program over to the Royal Air Force and the Air Ministry. Air Commodore Edward Maitland (1880-1921) was appointed Director of Airships. Convinced of the superior capabilities of the rigid airship for long distance commerce, Maitland attempted to demonstrate the potential of an airship passenger service by sending the R 33 on a round trip to the Netherlands with beds and a chef aboard on September 10, 1919.[32] Limited funds prevented the continuance of such demonstration flights. In fact, in an economy move on May 31, 1921, the British Government ordered the Air Ministry to sell all its airships to private firms or turn them over to the Disposal Board for scrapping by August 1.[33] The time of almost unlimited Government funding of rigid airship development in Britain had ended. Yet, when the August 1 deadline came, the R 33 managed to avoid the scrapper's torch; it was, in fact, laid up to fly again at a later date.[34]

Like the R 33, the R 34 first flew in March--on March 14, 1919. The R 34 was the "flagship" of the Air Ministry's efforts to "drum up" interest in long distance commercial aviation. Maitland saw the opportunity offered by an invitation from the president of the Aero Club of America to send an airship to the annual May meeting of the

organization. Yet bureaucratic delay and lackadaisical preparations insured that the R 34 would not be the first to fly across the Atlantic, but it was the first to fly a complete round trip.[35] Two months later, on July 2, at 2:42 A.M., Major George H. Scott, the captain of the R 34 gave the order to lift off. There were 30 men aboard, including Maitland and Lieutenant Commander Zachary Lansdowne, who represented the United States Navy. From the outset it was necessary to fly at an angle of 10 or 12 degrees up to achieve additional lift aerodynamically because of the heavy load being carried. Consequently, the flight was slow and fuel consumption was high. After encountering head winds over the North American coast, the R 34 landed at Hazelhurst Field, Mineola, New York, with only enough gasoline left to run its engines a further two hours.

As there were no hangars of sufficient size in the United States, the airship was tethered at Hazelhurst Field by its bow to a three-wire guy system that made staying very long a somewhat precarious venture. Three days after its arrival in the United States, the R 34 was turned back towards Britain, where it arrived only 75 hours and 3 minutes after departure from Hazelhurst Field. The British reaction to this extraordinary flight was silence. A truly great aviation achievement, which no airplane would match for over two decades, was ignored.

Like the R 33, lack of funds prevented the R 34 from flying much in 1920. On January 27, it left Howden on a training flight, after which it was to be turned over to the American crew in training. That night it struck a hill, damaging the control car and the propellers forward and aft. It was returned to Howden on two engines, but a gusty wind prevented housing the airship. Moored to a three-wire guy in the open, the airship suffered so much damage forward that the only feasible course was dismantling, which was done in February.

Of the three additional British "height-climbers" (the R 35, the R 36, the R 37) ordered by the Admiralty in January, 1917, only one, the R 36, was ever completed. The Armistice halted work on all three, but in 1919, the R 36 was permitted to be completed as a civil airship, receiving the civil registration G-FAAF. An enlarged L 33 type, this airship was built as a "height-climber" and astonishingly enough was expected to be a passenger vessel. Yet, to graft passenger accommodations onto a hull that was intended to be as light as possible with a very narrow safety margin was dangerous in the extreme. Considering that "height-climbers" could not safely be maneuvered below 7,000 feet and passenger airships were rarely flown above 2,000 feet (to conserve hydrogen and lift), the combination became preposterous. No fact could more

clearly illustrate the lack of understanding of the technology involved in early rigid airships. Truly, this is an industry that learned by bumps of knowledge.

Power for the strange hybrid was provided by two 350 horsepower Sunbeam Cossack engines in gondolas amidships and a third one located in the center line gondola aft. Two small gondolas attached to the hull forward contained Maybach MbIVa "altitude engines." Under the hull amidships was a cabin some 131 feet long and 8.5 feet wide. Equipped with wicker chairs, toilets, a galley, and two-berth cabins, this area was supposed to accommodate 50 passengers and 28 crew members. According to the Air Ministry, it was capable of carrying 30 passengers and a ton of mail to Egypt in three days. Yet we know now that its disposable lift would barely have enabled it to carry the fuel for such a trip, much less the passengers and mail.[36]

Fortunately, the opportunity for the Air Ministry to put its claims into practice never came because two months after its maiden flight the *R 36* was severely damaged forward while landing at the mast. The *R 36* was supposedly repaired in 1925, but it never flew again.

The last truly wartime British rigid airship was the *R 80*, built by the Vickers firm according to original plans drawn up by the design team headed by Barnes Wallis.[37] When the contracts for the 1916 and 1917 copies of the *L 33*

were given out, Vickers was excluded because its shed was too small; it also was refused the steel necessary to build a larger one. It, therefore, applied for permission to design and build a high performance airship that would fit in its shed on Walney Island. The Admiralty granted the request, and construction began late in November, 1917.

The hull of the R 80 was fully streamlined with an overall length of 535 feet and a maximum diameter of 70 feet. There were 16 main transverse ring frames, which except for being braced with wire rather than girders were quite similar to those used in the Zeppelin airships. Spaced evenly between these main rings were light intermediate ones. These rings were held in place by 11 primary longitudinal girders and 10 secondary ones, although the latter terminated just before the tail section. The three gondolas were fully streamlined: the forward one had a pair of 230 horsepower Wolseley Maybach engines connected to a large propeller aft and the other two, located to port and starboard amidships, had a single engine each. As there was no rear gondola, these port and starboard cars were equipped with impact absorption devices. In order to balance the mooring gear added to the bows after the R 80 was completed, a full ton of permanent ballast was carried aft. Even with this additional weight, the disposable lift of nearly 40,000 pounds was quite remarkable.[38]

The design and construction of the _R 80_ marked a significant stage in the development of rigid airships in Britain. Significantly enough, for the first time since the unfortunate _Mayfly_ broke its back in 1911, a British team designed a rigid airship without reference to a German prototype. Moreover, the resulting craft was as good as, and in some ways (such as the incorporation of the British innovation of a bow mooring cone) better than, its German contemporaries, the _Nordstern_ and _Bodensee_ (discussed in the next chapter). In innovative design the British had at last begun to match the Luftschiffbau Zeppelin. Yet, as part of the economy measures forced on the Air Ministry by the Government (and also because the British were concentrating on other things), the _R 80_ was eventually laid up and in 1925 scrapped.

France

Prewar French military interest in lighter-than-air craft was confined to the Lebaudy semi-rigid airships first successfully flown in 1902. As in Germany and Britain, there was little official desire to finance rigid airship development. Nevertheless, in 1912, an Alsatian, Joseph

Spiess, built a rigid airship (named after himself) that closely resembled the contemporary Schwaben of the German DELAG line (p. 106).[39] It underwent a series of modifications in 1913 to increase its lift (by adding gas cells) and increase its speed (by adding another engine); nevertheless, it made only one flight over Paris on January 16, 1914. The lift of the Spiess was still inadequate, and it was returned to its shed until after war broke out in August, when it was dismantled. Its lack of lift eliminated any potential military or commercial appeal.

During the War, the French restricted their active interest in rigid airships to the gathering of data from the German craft forced down in France that had begun with the German Z IV in 1913.

United States

Interest, especially military interest, in rigid airships was not confined to the European Powers. In the early phases of American participation in World War I, naval requirements (principally the need for anti-submarine patrols) underscored the same problem that the United States Navy had had in the Spanish-American War almost 20

years before: how to conduct operations in two oceans separated by the American mainland. The problem had been somewhat alleviated by the completion of the Panama Canal in 1914. Yet the Canal itself was vulnerable and it merely reduced the time needed to move the necessary vessels from one ocean to the other. For the Americans, the need to conduct reconnaissance on a grand scale before committing the naval units available, especially in the Pacific, was urgent.

The first step we know of was the sending of Lieutenant Commander Jerome C. Hunsaker U.S.N. on a reconnaissance mission to Europe in 1913.[40] While in Germany Hunsaker confined his examination of rigid airships to an inspection of the outside of the hull of the DELAG passenger airship Viktoria Luise and a flight in it over Berlin--his British predecessors (Jellicoe, Sueter, and O'Gorman) had done this a year and a half before in the Schwaben. He drew much the same conclusions as his British counterparts had done: "such an ideal scouting weapon will naturally be a part of every modern fleet . . . ."[41] Although he felt that small non-rigid airships could be quite useful for patrolling friendly coastal waters, he wrote that, "When we come to consider the fleet requirements for a strategic [air] scout, we must have an airship with an endurance in the thousands rather than hundreds of

miles. We have then got to think of the German Zeppelin [airship]."[42]

Gradually the Bureau of Construction and Repair of the Department of the Navy began to accumulate a body of useful information on rigid airship construction. In October, 1913, the American naval attaché in Berlin dispatched gas cell material scraps to the Bureau from the site of the explosion of the L 2 (October 17, 1913). These were correctly identified as goldbeater's skin. During the period of American neutrality in the First World War the attachés in Denmark, Norway, and France forwarded samples of girders from the wrecks of German airships brought down in those countries. When metallurgic analysis revealed these to be made of duralumin, the Bureau undertook negotiations with the Aluminum Company of America that initiated production of this aluminum copper alloy in the United States in 1916.

The inability of the British Royal Navy to bring the German High Seas Fleet to a conclusive battle in the North Sea and the initially spectacular success of the airship raids on London (that were reported before the government began censoring the news) forcefully brought the uses of the rigid airship to the attention of the General Board of the Navy. On June 24, 1916, this advisory committee of senior admirals recommended acquiring three non-rigid

airships, one of the semi-rigid type, and one rigid.[43] Furthermore, the General Board approved on October 19, 1916, a recommendation by Admiral Taylor and General G. O. Squier (the Chief Signal Officer of the Army) that the Navy and War Departments cooperate in the design and construction of rigid airships. This proposal was implemented with the creation of a Joint Airship Board on January 15, 1917. The Chief Naval Constructor was to direct the army and naval officers of this panel in designing a rigid airship of the Zeppelin type. Its Chief Engineer was a civilian, Starr Truscott.

While a technical committee appointed in December, 1917, by the Board to study airship development in Britain was abroad, Truscott evolved a design for an airship some 615 feet in length. Some of the features of the design, especially the wooden framework of the hull and probably the thick cantilever section tail fins, were strongly influenced by the ubiquitous Hermann Müller, formerly of the Luftschiffbau Schütte-Lanz and the airship program of the British Admiralty.[44] Besides the wooden girders, the proposed airship had other faults (for example, four engines mounted in the keel within the hull [totally impracticable with hydrogen in the gas cells nearby]), and the Joint Airship Board rejected it.

The report of the technical committee, however, prompted the Board on July 19, 1918, to propose the immediate procurement of four rigid airships, two of the British ones for use in Europe and two to be built in the United States.[45] The Navy was to have control of and responsibility for the construction of the American airships but was to provide the Army with full information regarding them.

The careers of the Luftschiffbau Schütte-Lanz and the rigid airship program of the British Admiralty had much in common. Both really developed as the result of the War and both faded quickly at its end. Moreover, both failed in their objectives: the Schütte-Lanz airships were only temporarily better than the Zeppelin counterparts, and no British airship ever flew a scouting sortie for the Grand Fleet. Yet, from the technological point of view, they both embodied some (if not many) advanced concepts in airship design. Nevertheless, one of the principal handicaps facing the Schütte-Lanz group in its effort to raise funds for new airships after the war was the poor reputation of its wartime airships. Like the Frenchman Spiess, they were condemned by what they had done.

Some of Britain's problems in the postwar period arose from its own two-faced attitude. While, on the one hand the British appeared eager to catch up with the Germans, on the other hand they never tired of belittling German efforts. They depicted the German rigids as highly overrated, ridiculously unmaneuverable, and a great waste of German resources. Despite all the efforts of the Air Ministry, British officialdom never really accepted the idea of German superiority--neither in rigid airships nor in anything else. Perhaps as we have hinted elsewhere, the British were never drawn to airships as the Germans obviously were. There is no "miracle of Echterdingen" in British aviation history.

Unlike the British, the American Navy did not adopt an airship program until the War had ended, although some information was accumulated and the necessary manufactories were encouraged. Whereas, in 1919, British naval interest in airships was waning, that of the Americans was really just beginning. Yet the course of the diffusion of airship technology (from Germany through Britain to the United States) ensured that the Americans would not only gain much but that they would also inherit many of Britain's technological weaknesses which would eventually undo British efforts.

NOTES

1. Johann Schütte, "Vorwort," in Der Luftschiffbau Schütte-Lanz 1909-25, ed. by Johann Schütte (Munich: Verlag Oldenbourg, 1926), pp. 1-2.

2. Ibid., p. 2.

3. Walter von Eberhardt, "Die geschichtliche Entwicklung der Luftfahrt und die Bedeutung der Persönlichkeit für dieselbe," in Unsere Luftstreitkräfte, p. 10

4. George E. Wright, "Germany's Giant Wooden Warriors," Air Classics, Vol. VIII, No. 4 (February, 1972), p. 17.

5. William L. Marsh, "The Evolution of Rigid Airship Design," Air Annual of the British Empire, Vol. II (London: Gale & Polden, 1930), p. 96.

6. Germany, Militärgeschichtlichen Forschungsamt, Die deutschen Luftstreitkräfte, "Der Kriegsminister an den Chef des Generalstabes der Armee," April 14, 1914, document #52, p. 103.

7. Roeser, "Aus der Geschichte des deutschen Starrluftschiffes," in Der Luftschiffbau, ed. by Schütte, pp. 139-40. "Schütte-Lanz-Luftschiffe für die Armee," Deutsche Zeitschrift für Luftschiffahrt, Vol. XVII, No. 5 (May, 1913), p. 370-1.

8. Letter, Schütte "An Seine Exzellens den Herrn Admiral v. Müller, Chef des Marinekabinetts Sr. Majestät des Kaisers und Königs," April 24, 1909, National Archives, "Tambach Archives" (Kriegsarchiv der Marine), microfilm roll no. T1022/637, PG 67397.

9. United States, Department of State, The Treaty of Versailles and After, p. 354.

10. Schütte, Der Luftschiffbau, p. 4.

11. Great Britain, Admiralty, Air Department, Handbook on Rigid Airship No. 1 (confidential) (London: HMSO, 1913), Appendix A.

12. J. E. Morpurgo, Barnes Wallis, A Biography (London: Longman Group, 1972), p. 52.

13. Great Britain, Admiralty, Air Department, Handbook, Appendix A.

14. Ibid.

15. F. L. M. Boothby, "Early Days of the R. N. Airship Section," The Airship, Vol. V, No. 19 (September - December, 1938), p. 35.

16. "The Airship for the British Navy," Engineering, Vol. XCI (February 17, 1911), p. 222.

17. An innovation that became standard equipment on postwar American rigids. J. A. Sinclair, Airships in Peace and War (London: Rich & Cowan, 1934), p. 27.

18. Morpurgo, Barnes Wallis, p. 53.

19. Sinclair, Airships, p. 28.

20. Walter Raleigh, The War in the Air, Vol. I (London: Oxford University Press, 1922), p. 181.

21. "The Evolution of the Airship--(I)," Aeronautics, Vol. XVI, No. 297 (June 26, 1919), p. 664.

22. "The Evolution of the British Naval Airship," Engineering, Vol. CVII, No. 2789 (June 13, 1919), p. 757.

23. "Evolution," Aeronautics, p. 665.

24. Ibid.

25. The R designation was appended to the numbers of all rigid airships beginning in 1916.

26. This incident was all but totally buried by the Official Secrets Act until it was dug out by Higham in an interview with an American survivor. Robin D. S. Higham, The British Rigid Airship, 1908-31 (London: G. T. Foulis & Co., 1961), pp. 152-3.

27. The close resemblance had led one writer to conclude that Müller smuggled actual Schütte-Lanz plans out of Germany. Robinson, Giants, p. 158.

28. Christopher Sprigg, The Airship: Its Design, History, Operation, and Future (London: Sampson, Low, Marston & Co., 1931), p. 113.

29. These tests were among the first scientific attempts to analyze the behavior of the frame of an airship while in flight. The findings are published in three parts. Great Britain, Air Ministry, Aeronautical Research Committee, J. R. Pannell, R. A. Frazer, and H. Bateman, Experiments on Rigid Airship R 32, Parts I-III, Reports and Memoranda, No. 811-3 (Aeronautics 62-4), February - May, 1921 (London: HMSO, 1923).

30. John Jellicoe, The Grand Fleet, 1914-16 (London: Cassell & Co., 1919), p. 439.

31. The plans copied from the L 49 were passed to the British and the Americans.

32. Almost all the airships possessed by the Air Ministry were too lightly built and insufficient in lift to serve as passenger craft. Unaware of this, Maitland was determined to prove the feasibility of converting the ex-Admiralty airships for this use. George Meager, My Airship Flights, 1914-1930 (London: William Kimber, 1970), pp. 131-2.

33. Higham, The British, p. 198.

34. It will reappear as a test airship for the R 100 and R 101.

35. A United States Navy NC-4 seaplane crossed to England on May 31, 1919, and Alcock and Brown flew from Newfoundland to Ireland on June 14-5.

36. See Appendix A.

37. Morpurgo, Barnes Wallis, pp. 76-7.

38. Comparative figures for airships of similar size (completed in the same shed) were: No. 9, 4,700 pounds, R 26, 13,000 pounds.

39. Cuneo, Winged Mars, p. 149. See Appendix A.

40. Jerome C. Hunsaker, "The Navy's First Airships," U. S. Naval Institute Proceedings, Vol. XLV, No. 8 (August, 1919), p. 1349.

41. Jerome C. Hunsaker, "Use of Airships with the Fleet," U.S. Air Services, Vol. I, No. 3 (April, 1919), p. 9.

42. Jerome C. Hunsaker, "Naval Airships," Transactions, Society of Automotive Engineers, Vol. XIV, Part I (1919), p. 582.

43. Hunsaker, "The Navy's First," pp. 1355-6.

44. Garland Fulton, "Rigid Airships," Part II, U.S. Naval Institute Proceedings, Vol. XLVII, No. 11 (November, 1921), pp. 1713-4.

45. Ibid., p. 1714.

CHAPTER VII

THE PLACE OF THE AIRSHIP IN POSTWAR MILITARY AVIATION

By now, the preponderant role of German technology in the development of the rigid airship will have become apparent. However reluctant the British may have been during the War to copy German designs, they knew that their national security depended (to some extent at least) in their keeping abreast of German developments. Some of this knowledge of German progress they obtained themselves; some was handed on by allies and neutrals. In this way was Germany's superior technology diffused to other lands. This process reached a culmination with the end of the War when the German airships became the spoils of the victors. Under Article 202 of the Versailles Treaty, all rigid airships "able to take [to] the air, being manufactured, repaired, or assembled" had to be surrendered.

Italy

Three of the sequestered airships (the L 61, the LZ 120, and the Bodensee) were taken by Italy. After the L 61 was brought to Ciampino (near Rome) on August 30, 1920, it was renamed Italia, but made few flights before sustaining damage while landing in January, 1921. As no spare parts were available for repairs to be made, the Italia was dismantled. The LZ 120, restyled the Ausonia upon its arrival at the Ciampino base on December 25, 1920, was deflated and stored in a hangar there until a storm in June, 1921, caused part of the roof of the building to collapse, wrecking the airship. The Bodensee, although built as a passenger airship in an attempt to revive the DELAG line, was seized under the pretext that the materials used in its structure were manufactured during wartime for use in projected naval airships. It was turned over to the Italians on July 3, 1921, and redesignated the Esperia.

Unlike the two high altitude wartime airships, the Esperia was flown extensively over a period of seven years until its decommissioning and dismantling in July, 1928.[1] This performance which included several flights across the Mediterranean Sea illustrated the significance of the heavier, stronger structure of the postwar passenger airships which withstood handling that no lightly built "height-climber" would. Nevertheless, as Italian interests

were confined to the Mediterranean area, there was no need for long range aircraft such as the rigid airship. Instead, Italian interest in airships was concentrated on the semi-rigid type, the most notable examples of which (the Norge and Italia) were designed by a native son, General Umberto Nobile, and used in Polar exploration.

France

France's position was different than Italy's. Its large colonial empire with widely separated naval bases, as well as truly worldwide commercial interests, could be greatly helped by improved transport and communications. For France, the rigid airship offered an improved system of rapid colonial transport as well as supportive strategic reconnaissance craft for the French Navy.

It was only too pleased in 1919 to receive three of the rigid airships confiscated by the Interallied Control Commission. In addition, the last wartime airship completed by the Zeppelin works, the L 72, was delivered to the French base at Maubeuge on July 13, 1920. It was assigned to the French Navy, renamed the Dixmude, and

placed under the command of Lieutenant Jean du Plessis de Grenedan (1892-1923). A convinced advocate of the value of a long range airship for naval reconnaissance, du Plessis wanted to use the *Dixmude* to demonstrate the capabilities of rigid airships for the French Navy.[2] Instead, he was notified that the *LZ 113* was to be brought to Maubeuge in October and the *Dixmude* would be scrapped to make room for the new arrival unless he could fly it out of the hangar. On August 11, 1920, du Plessis and his crew, which had never before flown a rigid airship, took the *Dixmude* to Cuers-Pierrefeu, a base near Toulon. There the *Dixmude* remained in limbo for three years. Initially, the government, burdened by debts incurred during the war, refused money for its operation. In September, 1921, du Plessis secured funds for hydrogen, but the attempt to inflate the *Dixmude* revealed that the old German gas cells had decayed. When du Plessis suggested ordering new cells from the Ballon-Hüllen-Gesellschaft (the Zeppelin subsidiary that manufactured goldbeater's skin gas cells) through an intermediary, the Ministry of Marine (following the French tradition established by Colbert) opted to establish a new industry in France for their manufacture, letting the contract to the Astra-Nieuport firm.[3]

The cells were delivered and installed in September, 1923. These, too, were defective, du Plessis noting that

the cells developed small tears during flight that were not caused by faulty installation but rather through the use of inferior cotton material in the fabrication of the cells.[4]

Nevertheless, du Plessis considered a demonstration flight essential for the justification of past and possibly future expenditures on an airship program. The Dixmude was the only airship available capable of making the ambitious flights suggested by du Plessis and approved by the Ministry of Marine. Either for reasons of economy or lack of a crew with even the most rudimentary training, the LZ 113 (which had been assigned to the Army upon its arrival at the vacated hangar at Maubeuge on October 9, 1920) had never been flown. It was dismantled within a year. The Nordstern, the second of the airships Eckener built (along with the Bodensee) after the war for DELAG service, also had been initially assigned to the French Army at its base at St. Cyr where it arrived on June 13, 1921. As the Méditerranée, it remained under army control at St. Cyr for a year, making several flights for the purpose of training crewmen for du Plessis' Dixmude. On July 28, 1922, Lieutenant Stapfer symbolically formalized naval assumption of proprietary rights by flying the Méditerranée to the naval base at Cuers. Although du Plessis recognized the value of the Méditerranée, he knew

that its maximum useful lift (25,350 pounds) was quite insufficient for the planned flights around the western Mediterranean Sea as well as to Dakar, the French naval base on the west coast of Africa.[5]

After two "dry runs" in early August, 1923, du Plessis began his schedule of flights later that month. On completion of the second round trip to North Africa a month later (September 28) he decided to take the Dixmude to Paris, simultaneously setting a new endurance record and promoting public enthusiasm.[6] Further promotional flights in the south and west of France followed in October. The airship went out as a scout in fleet exercises off Bizerta (Algeria) during November 21-4, but a severe widespread storm in the western Mediterranean blocked the way back to Cuers. Because there were no adequate hangars in North Africa, du Plessis took the airship into the turbulent thunderstorm. After an exhausting battle, the Dixmude landed safely at Cuers apparently intact.[7]

Preparations for the next Mediterranean-North African flight proceeded smoothly. The airship lifted off from Cuers for In Salah, an oasis near the southern border of Algeria on December 18, 1923. On the return half of this trip, another Mediterranean storm barred the path of the Dixmude. Du Plessis gave up trying to force his way through after battling headwinds for four hours and turned

east to try to use the counter-clockwise cyclonic winds to boost the airship homeward. At 2:08 A.M., the radioman sent the message that the antenna was being reeled in because of the storm.[8] Within 20 minutes the airship was seen approaching Sicily. Suddenly a terrific explosion converted the Dixmude into a fireball that slowly fell to the sea. Of the 50 men (40 crew and 10 passengers), none survived.

Although the explosion was witnessed indirectly by several Sicilians and bits and pieces of the wreck were blown or washed ashore during the next few days, the French government acted as if nothing had happened. When this could no longer be believed, it merely stated that the Dixmude was missing. All doubt came to an end with the recovery of the corpse of du Plessis on December 26.[9]

The testimony of the Sicilian witnesses and the evidence provided by the scraps and fragments recovered from a subsequent search in the area where the airship was seen going down provide a fairly clear idea of the causes of the destruction of the Dixmude. Either the leaky gas cells permitted considerable inward diffusion of air or the airship was subjected to a strong updraft that lifted it above its pressure height causing hydrogen to be expelled into the ionized atmosphere. A lightning bolt (ordinarily harmless to an airship) struck the Dixmude and ignited the

explosive oxy-hydrogen mixture. The resulting explosion shattered the possibly weakened frame of the hull and the airship disintegrated in mid-air.[10]

The loss of du Plessis and the Dixmude effectively brought an end to postwar French military interest in airships, though the Méditerranée was used for test flights and experiments until its decommissioning in August, 1926. Yet it was too small to serve any really useful purpose. After the removal of all accessories, its hull was tested with increasingly greater loads in September until it collapsed. Despite earlier enthusiasms, the Aviation Department of the Ministry of Marine had supported du Plessis only with some degree of reluctance. With his death the enthusiasm and backing he had created with the spectacular flights of the Dixmude evaporated and the Aviation Department turned to heavier-than-air craft.

Britain

The postwar military rigid airship program in Britain, like that of France, hung on the fate of a single airship. As we have seen, other military rigid airships (such as the R 33 and the R 34) were completed and first flown after the

end of the War in Britain, but it was on the R 38 that the Admiralty pinned its hopes for rigid airships. The R 38, designed by Constructor-Commander C. I. R. Campbell, was to be able to cruise for six days as far as 3,000 miles from its base. The Admiralty order for it was placed with the Short Brothers Works at Cardington, but in February, 1919, the Short Brothers establishment was nationalized and redesignated the Royal Airship Works. Consequently, the construction work was carried out directly under the control of the Admiralty.

Campbell consciously attempted to excel his German counterparts in every important aspect--size, lifting capacity, ceiling, range, and speed--of this design.[11]

The hull of the R 38, of a highly streamlined design, was some 699 feet long with a maximum diameter of 85.5 feet. The frame consisted of 13 main longitudinals and 12 secondary ones supporting main rings spaced almost 50 feet apart with two light intermediate rings between each of these. The main rings had diamond-shaped trusses in place of the kingpost bracing then used in the Zeppelin design. Instead of the triangular keel common to Zeppelins and most other airships, the cross-sectional configuration of the keel corridor of the R 38 was trapezoidal and thus potentially unstable under stress. The small control cabin was built onto the bottom of the hull well forward, as had

been done in the R 31 and the R 32. Fourteen gas cells contained 2,724,000 cubic feet of hydrogen. To attain a combat ceiling of 22,000 feet with fuel for 65 hours at full speed, Campbell deliberately made the hull as light as possible; so much so that (as it was later revealed) he had calculated only the static loads in the hope that aerodynamic stresses would not exceed these by more than a factor of four.

Yet the six Sunbeam Cossack engines (each of 350 horsepower) carried in three pairs of gondolas beneath the hull were intended to drive the R 38 at 70.6 miles per hour. The bending loads imposed on the hull when turning at speed were much greater than what little previous experience the British had acquired (mostly with wind tunnels) had indicated, and the R 32 experiments conducted by the National Physical Laboratory remained incomplete.

The postwar economy drive brought a request from the Treasury to cancel the R 38 and the other airships of similar design under construction or being planned (the R 39, the R 40, and the R 41). All except the R 38 were subsequently dropped. Yet, work on the R 38 continued because the Admiralty wanted to complete a prototype of the advanced design. The continued erosion of funds, however, soon convinced the Admiralty that selling it to the Americans might provide a convenient method of gaining

the experience of constructing the R 38 and yet unloading the completed airship before its upkeep became a burden on the Admiralty's funds. In October, 1919, the first two rings of the R 38 were erected. On October 9, the British Cabinet approved the sale of the airship to the American Government for £300,000.[12] American personnel to fly it back to the United States were to be trained in British airships while the R 38 was being completed.

Misgivings about the structural strength of the new airship were expressed by various officers concerned with testing it. H. C. Dyer, the American representative at the site of construction in Cardington, complained that he could obtain no figures on safety calculations, factors of safety of the main rings, or strength in a turn with the rudders put hard over.[13] He could not know that there were none to be had. Campbell was no longer in charge of construction of the airship, having been promoted to manager of the Royal Airship Works; moreover, he frequently travelled to the United States as a consultant for the designers of the airship to be built there. Flight Lieutenant J. E. M. Pritchard, the British officer in charge of trials, wanted a minimum of 150 hours of total test flying in all weathers. Moreover, he recognized the necessity of testing the R 38 as the Germans tested their "height climbers"--at a minimum altitude of 7,000 feet.[14]

Maitland, the Director of Airships, although not a technician like Pritchard, favored at least 90 hours of testing.

Nevertheless the need for economy backed by the reassuring opinions of the Director of Research of the Royal Air Force and Commander Louis H. Maxfield, the American who was to take command of the airship upon completion of the trials (who saw no need of more than 50 hours of testing), insured that the lower figure would be the one chosen.

Yet the test flights immediately indicated problems. Flights on June 23-4 and June 28-9 revealed rudder balance problems and weaknesses in the cantilevered fins, which were subsequently braced with external wires. On July 17-8, the R 38 was flown from Cardington to Howden. During the flight, the R 38 was brought up to 57 miles per hour and began ranging vertically over a distance of 500 feet. Pritchard took control and reduced the speed. Transverse girder failures amidships were also reported; however, Pritchard completed the flight safely at a lower speed. The true cause of the failure, excessive aerodynamic forces at high speed, was completely ignored, but some reinforcement was added while repairs were being made.[15]

On August 23, 1921, the R 38 departed Howden for Pulham where it was to be loaded for the transatlantic

flight. The final tests were to be conducted during this flight to Pulham. Fog at this destination provided an excuse to stay aloft overnight, and further turning tests were scheduled for the following day. The fog did not dissipate, however, and it was decided to return to Howden. A final high speed test was completed as the airship approached the city of Hull late the afternoon of August 24. At an altitude of 2,500 feet and a speed of 62.8 miles per hour, the turning trials commenced (who ordered them has never been determined). The rudders were switched from port to starboard and then back again with the angle steadily increasing until the aerodynamic forces exceeded what the light frame was capable of withstanding.

At 5:37 P.M., the longitudinal girders in the top of the bay abaft the rear engines fractured, and the R 38 broke in two in that area. Two considerable explosions alerted those citizens of Hull who were not already transfixed by the awful spectacle above their heads. As they watched, both sections fortunately fell into the Humber River; otherwise, the disaster might have been compounded tenfold. Of the 49 men aboard, there were but five survivors, and four of these were in the tail section. Sixteen of the 26 Americans in Britain for training were lost, as were Air Commodore Maitland, Pritchard, Campbell, and J. R. Pannell of the National Physical Laboratory.

The investigations that followed the accident rapidly focused attention upon the faulty design of the airship and Campbell's lack of calculations of, or even knowledge about, aerodynamic loads (especially in turning). A report from the Aeronautical Research Committee's subcommittee that conducted the investigation stated:

> (a) That the accident was due to structural weakness in the design of the airship . . . . (c) That, having regard to her size and speed, R.38 (sic) was considerably weaker than previous British rigid airships. (d) That the provision of specially powerful control surfaces of new design virtually accentuated this weakness . . . . (g) That . . . the movements of the controls necessary to keep her on any particular course were large and rapid.. . . .[16]

Whereas the statement concerning the legitimacy of the use of the controls is debatable, the conclusion of inadequate structural strength is not. As Maitland, Campbell, and Pritchard outranked the Flight Lieutenant in nominal command of the R 38, it is apparent that none of them objected to the maneuvers of the turning test, or they would have been stopped. Not realizing that the design of the hull, its method of construction, and the materials in it did not have the strength necessary to offset the forces applied by maneuvering at high speeds at low altitudes, they stood by as the irreversible disintegration of the duralumin longitudinals under stress began. Limited understanding of the technology involved led them to believe that the R 38 was sufficiently strong to endure the worst--but it was not.

The destruction of the _R 38_ (or the _ZR 2_ as was to be its American designation),[17] originally intended to secure Britain a place of leadership in the development of rigid airships, seemed to put an end to British postwar airship developments.

United States

In the United States, however, work proceeded on the _ZR 1_ (the Navy's American-built rigid airship). In 1918 the American government had committed itself to purchasing two rigid airships abroad and building two in the United States (p. 183). The termination of the War in November caused this plan to be abandoned in favor of a more modest proposal to acquire two airships, one abroad and one in the United States. In 1919, Congress appropriated the necessary funds for these airships and for the establishment of an airship base.[18]

The site chosen for this base was the Army's Camp Kendrick in New Jersey. An immense hangar with unobstructed inner dimensions of 804 feet (length) by 264 feet (width) by 193 feet (height) was erected and the base was renamed United States Naval Air Station Lakehurst on June 28, 1921.

While the British-American negotiations concerning the purchase of the R 38 (the airship to be purchased abroad) had been going on in Britain, the United States Army violated the established policy of the Joint Airship Board by initiating an attempt to buy a large rigid airship directly from the Zeppelin Company in Friedrichshafen. Colonel William N. Hensley was dispatched to Europe in July, 1919, by General William Mitchell, then Chief Training and Operations Officer of the Army Air Service, ostensibly to secure information on rigid airships. On August 20, however, he was ordered by the War Department to undertake negotiations with the Luftschiffbau Zeppelin.[19] On November 26, 1919, Hensley and Alfred Colsman signed a contract for the LZ 125, which was to be a close replica of the L 100 that had been proposed for the German Navy before the end of the war. The cost was approximately $500,000. Although forbidden to build large airships by Article 201 of the Versailles Treaty, the Zeppelin works began construction of the new airship. However, the Secretary of War (Newton D. Baker), whose approval of the attempt to acquire a rigid airship despite official policy has not been explained, apparently realized that there was no possible justification for the orders upon which Hensley had acted and cancelled the whole project.[20] The United States Army never acquired a rigid airship.

The design of the airship of the 1919 naval program approved by the Joint Airship Board that was to be built in the United States was based upon the information obtained from the British and French on the German airships forced down during the war. The plans of the L 49 were given to Hunsaker after the Armistice and these were used as a starting point. After a number of design changes, the ZR 1 was 680.25 feet in length and 78.7 feet in maximum diameter, somewhat larger than the L 49 (as was the gas capacity of 2,115,174 cubic feet). Structural details were essentially identical to those in the L 49, including the spacing of the kingpost braced main rings 32.5 feet apart with intermediate rings midway between them. These were held in place by the 13 main longitudinals and 12 intermediates, all of duralumin. The bow was reinforced and equipped with a mooring cone attachment.

Control was effected by flat cantilever fins while power was provided by six Packard 300 horsepower engines. One of these was located in a gondola centered beneath the sixth main ring from the stern of the airship while four were in gondolas mounted to port and starboard in pairs at the ninth and twelfth rings, and the sixth engine occupied the rear of the control car, which (as in wartime Zeppelin practice) was separated from the hull of the airship.

All of the parts were manufactured at the Naval Aircraft Factory in Philadelphia, beginning in November, 1921, and then shipped to Lakehurst where they were assembled. The work was completed and inflation of the gas cells began on August 13, 1923. When the ZR 1 lifted off on its first ascent on September 4, 1923, it became the first rigid airship to fly with helium instead of hydrogen.

This rare inert gas was a virtual American monopoly as the only quantity of it sufficient to make extraction feasible was present primarily in natural gas wells within a 250 mile radius of Amarillo, Texas. At the instigation of the British Admiralty, the Joint Airship Board on July 26, 1917, directed that some $480,000 was to be made available to establish experimental helium plants in Fort Worth near one of the gas fields. These went into production in the first five months of 1918, producing helium of 90 per cent purity. Another large plant started operation in 1921. Although control of these plants passed from the navy to the Bureau of Mines on July 1, 1925, the bulk of the production continued to supply at least the minimal needs of the Navy's airship program, and another large plant completed near Amarillo in 1929 assured an adequate future supply.

The principal advantage of using helium is that it is non-flammable: the constant fear of immolation was eliminated. Yet its use as a lifting gas was hindered by its scarcity and cost. Initially, its cost when produced in a laboratory was $2,500 per cubic foot, but in the plants built at Fort Worth, the cost was reduced to about 5.5¢ per cubic foot (as opposed to .002¢ per cubic foot for hydrogen).[21] Consequently, replacing the gas lost through maneuvering or "blowing off" at pressure height was costly. The problem was compounded by the smaller but heavier atomic structure of helium (as opposed to the molecular structure of hydrogen) which permitted it to diffuse comparatively rapidly through the walls of the gas cells while providing less lift, making it imperative to keep the cells as full as possible.

A number of expedients were used to avoid losing gas in the ZR 1 or the Shenandoah (meaning "Daughter of the Stars"), as it was christened. Heavy water recovery apparatus was installed to prevent valving when landing because of consumption of fuel. The 20 gas cells were connected by a fabric manifold intended to permit replenishing from a mooring mast connection but the airship's captain (Lieutenant Commander Zachary Lansdowne), acutely aware of the expense of replacing the gas lost, had removed eight of the maneuvering valves because they could

not be made leak proof. Moreover, the Bureau of Aeronautics reluctantly approved his proposal to remove 10 of the automatic valves with the warning that the gas cells of the *Shenandoah* could not tolerate ascents made at a rate greater than 400 feet per minute.[22]

For two years the *Shenandoah* was used both as an experimental vessel and as a publicity symbol for the Navy although it was laid up for four months for repairs and modifications (including the removal of the engine abaft the control car) after a gale tore it from the mooring mast at Lakehurst on January 16, 1924, and again when it was deflated from October, 1924, to June 26, 1925, so that the helium could be used in the airship that took the place of the *R 38* (the *ZR 2*). Another series of publicity flights to the Midwest were scheduled, but these were postponed until September because Lansdowne felt that the excessive summer heat would perhaps dangerously decrease the lift of his airship.[23] Instead, the *Shenandoah* became the subject of experiments in fleet operations, including mooring to the tender *Patoka* and scouting exercises for the summer.

On September 2, 1925, the *Shenandoah* left its mast at Lakehurst on the first part of its proposed itinerary. Early the next morning (4:20 A.M.), a severe storm was encountered near Ava, Ohio. Caught in a series of violent

vertical gusts, the airship rose rapidly, leveled off at 3,000 feet and then was hurled to over 6,000 feet at the rate of nearly 1,000 feet per minute. The airship then fell to 3,000 feet again before being caught in yet another vertical draft. Another current hit the forward section of the hull, forcing the bow of the Shenandoah up to an angle of almost 30 degrees. Strained beyond its capacity to resist, the duralumin frame broke in two forward of the rear pair of engine gondolas. As the sections finally parted, another break occurred near the forward engine cars. The section of the frame above the control car disintegrated and the gondola (and those within it) plunged to destruction. Fourteen of the 43 men aboard the airship were killed. Loss of life was not greater because the helium gas did not explode or burn and many of the crew members were able to ride the section they were in gently to the ground.

The findings of the Court of Inquiry were that the final destruction of the Shenandoah resulted from "large, unbalanced, external aerodynamic forces arising from high velocity air currents."[24] The blast of air that had hit the bow had compressed the upper longitudinals amidships because the partially deflated gas cells had imparted a sagging force to the frame there.[25] One result of the accident was a re-evaluation of structural requirements

by American aeronautical engineers. In the two other airships built in the United States for the Navy, the frames were made stronger, the engines were enclosed within the hull, and the control gondola was built onto it.

The Shenandoah had been deflated for some eight months (October, 1924, to June, 1925) to provide helium for the airship that took the place of the ZR 1. This was the ZR 3, the Los Angeles, which came into existence as the result of a phenomenal series of chance events. Of the German naval airships destroyed by their crews on July 23, 1919, two were to have been allotted to the United States.[26] In the summer of 1921, the Allied representatives decided to sequester the Nordstern and the Bodensee for France and Italy while the wording of the compensation offered to the United States stated that it would be compensated in monetary payment or in kind. After some negotiations between the Americans and the representatives of the Zeppelin company (who were well aware that this represented probably the only chance of loosening the restraints imposed by the Treaty), the United States representative at the Council of Ambassadors in Paris was finally able to demand support from the British after the crash of the ZR 2 in August, 1921, and the restrictions were lifted to permit the construction of an airship of 2,500,000 cubic feet capacity for civil purposes.[27] A

contract for the construction of the airship for some $750,000 was signed on June 24, 1922.

As completed with a gas capacity of 2,624,000 cubic feet, the LZ 126 (its factory designation) was slightly larger than any previous airship built by Luftschiffbau Zeppelin. The streamlined hull was 658.3 feet long and 90.7 feet in maximum diameter. The ring and girder structure corresponded to the wartime Zeppelin airships except that the rings had diamond truss bracing and the framework was built sturdier than in the "height climbers," partly as a consequence of adding the bow mooring fittings. The five engine gondolas were arranged in the usual pattern, but they contained a new type of Maybach engine, the VL-1 of 400 horsepower. The "for civil purposes" requirement resulted in an elongated control car with the passenger accommodations in the rear section. Electricity for this section as well as for lighting was provided by propeller driven generators mounted in the slipstream. Test flights of the airship began in August and carried through September as Eckener endeavored to show the new airship to his countrymen, the better to create support for the company.

Although apprehensive of crossing the Atlantic by airship (it had only been done once before by the British R 34), Eckener delivered the LZ 126 to Lakehurst on October 15, 1924, achieving celebrity status for himself and the

crew in the process. At Lakehurst the hydrogen used on the flight from Germany was replaced with helium from the Shenandoah and water recovery apparatus was added to the engines. The airship emerged from these alterations as the ZR 3, but it was christened as the Los Angeles by Mrs. Coolidge and commissioned into the Navy.

The remarkable career of the ZR 3 lasted almost eight years. During that time, the airship completed 328 flights, totalling almost 4,100 hours in the air. Although it experienced some near mishaps, especially after an aborted flight to Minneapolis when it was discovered that the calcium chloride used as antifreeze in the ballast bags had caused serious corrosion of the girders at many points, the only spectacular misadventure occurred on August 25, 1927, when a sea breeze caught the tail of the Los Angeles, which was moored to the high (160 feet) mast at Lakehurst, and brought the airship to a near-perfect vertical bow stand after which it pirouetted and returned to the horizontal right side up but facing the opposite direction. There were no injuries to the 25 men aboard and the only damage incurred was caused by loose objects falling through the fabric at the bow.[28]

The Los Angeles served a dual purpose before its decommissioning in 1932. Large numbers of naval officers and enlisted men received training in rigid airship handling

aboard it (seven commanders alone). Moreover, it was the subject of technical experiments to provide information for the design of the next generation of naval rigid airships. Moving an airship from a hangar had always presented problems: with the Los Angeles, the use of a mobile short mooring mast for this purpose was perfected. Experiments with releasing airplanes from airships had been conducted by the British and Germans during the First World War, but in December, 1928, the Los Angeles was fitted with a trapeze-like bar that permitted airplanes either to be released or to hook back on.

The importance of this innovation was underscored when permission was finally obtained from the former Allies to use the Los Angeles in a fleet exercise problem in February, 1931, involving the defense of the Panama Canal against an attack from a fleet in the Pacific. Despite its misuse as a tactical rather than strategic scout, the Los Angeles was the first unit to spot the enemy fleet although it was considered "shot down" by airplanes from the carrier USS Langley. Opinions of its performance varied with the prejudices of those who gave them, but the advantages to be obtained by scouting with small, fast airplanes operating from a flying aircraft carrier hidden in the clouds was made fairly obvious.[29]

The genesis of the next (and last) generation of United States naval airships occurred, however, in March, 1924, when Starr Truscott of the Bureau of Aeronautics' Lighter-Than-Air Design Section (and formerly of the design staff of the old Joint Airship Board) proposed an airship of 6,000,000 cubic feet capacity that would carry four fighter aircraft for defense and observation.[30] Admiral William A. Moffett of the Bureau was able to obtain authorization for the construction of two airships of this size from Congress in 1926 despite the strong opposition resulting from the wreck of the Shenandoah, but the call for bids produced only one serious entry, that of the Goodyear-Zeppelin Corporation. A protest by another company, the American Brown-Boveri Corporation, brought about a year's delay while another competition was held, but the results were the same.[31] The contract for the two airships, to cost $5,375,000 for the first and $2,450,000 for the second, was signed on October 6, 1928.

The Goodyear-Zeppelin Corporation was brought into existence in October, 1923, when Paul W. Litchfield, the president of Goodyear Tire and Rubber Company, formed a partnership through an intermediary with Eckener of the Luftschiffbau Zeppelin, who believed (not unreasonably) that the Zeppelin Company was finished in Germany. The new company received the North American rights to all

Zeppelin patents, as well as access to the engineering and operating experience of the firm.[32] Moreover, in October, 1924, Karl Arnstein, the Zeppelin company's chief designer, and 11 other engineers, emigrated to the United States to establish fully the engineering capabilities of the American transplant.

The design Arnstein produced exceeded the specifications set forth in Truscott's proposal. The two airships (designated the ZRS 4 [the Akron] and the ZRS 5 [the Macon]) were 785 feet long and 132.9 feet at greatest diameter. At maximum inflation, the gas cells contained 6,850,000 cubic feet of helium. As a result of the Shenandoah experience, the hull of each airship was to be quite strong: there were 36 longitudinals, three keels (one at the top and two to port and starboard in the lower hull), and 12 main frames, 10 of which were stiff deep triangular rings: they were spaced 24 feet apart and separated by three intermediate rings. The eight Maybach VL-2 560 horsepower engines were housed in line, four to a side in the lower keels, and above each of these was water recovery apparatus. The gas cells were of cotton fabric coated with a synthetic latex that was considerably lighter than goldbeater's skin. The most remarkable feature, however, was the airplane hangar amidships. This was designed to hold five airplanes which could be launched and recovered

by a trapeze that extended through a rectangular hole measuring 30 feet by 24 feet in the bottom of the hull.

Construction of the ZRS 4 began on November 7, 1929, and its first flight occurred on September 23, 1931. Through the first year of its existence, the Akron was plagued by material deficiencies and operating difficulties. On February 22, after it was brought out of the hangar at Lakehurst, the tail came loose from the anchoring device and smashed its lower fin into the ground repeatedly as the airship veered with the wind. Extensive repairs were carried out while the trapeze was being added. The same thing occurred again on August 22, putting the Akron under repair for three weeks. Finally in September, 1931, all the Curtiss F9C-2 airplanes that were to be carried aboard were delivered. In the next few months the pilots worked out a doctrine for the use of such aircraft that emphasized scouting rather than defensive fighting.

A few months was all the time they had, for on April 3, 1933, the Akron set out from Lakehurst on what was to be its last flight. Prepared for a two or three day flight to calibrate radio direction finding stations along the New England coast, the Akron became entrapped in a storm off the New Jersey coast late the night of the first day. Just after midnight in a heavy rain squall, the ship began falling rapidly. Turbulent air continued to buffet

the airship after ballast was released to stop the fall. The altimeter read 700 feet when the *Akron* levelled off. It started falling again, but this time the elevators were put up to raise the bow and the engines were opened to full throttle. As the angle of the airship exceeded 20 degrees, a sharp shock was felt as the lower fin struck the sea. Unable to bear the strain, the midships section began breaking and the *Akron* settled into the sea, which was sighted from the control car when the altimeter read 300 feet.[33] Within moments the control car was being flooded. Altogether 73 men died (including Admiral Moffett) and only three survived.

Those controlling the *Akron* had made the error of relying on the altimeter, which, because it was based on barometric pressure, could very easily have been giving readings as much as 600 feet too high in the low pressure area of a storm. Consequently, when the rudders were put up to make the bow rise, they also made the stern fall with insufficient room to clear the sea. The force of the water acting upon even such a strongly built frame as that of the *Akron* was too severe.

Although the *ZRS 5* (or the *Macon*, as it was christened by Admiral Moffett's wife on March 11, 1933) embodied some minor improvements over the *Akron*, it was essentially an identical airship. It made its first flight on

April 21, 1933, and was commissioned on June 23. After a few months spent training the airplane pilots at Lakehurst, the _Macon_ was dispatched to California where it was to undergo evaluation as a participant in fleet exercises. As the _Los Angeles_ had been, it was used in tactical situations for which it was eminently unsuited, and its record provided critics with plenty of information when Admiral David F. Sellers, the Commander in Chief of the United States Fleet, made his unfavorable report.[34]

As the _ZRS 5_ was supposed to proceed to the Caribbean to participate in exercises there, its commander, Alger Dresel, sought permission to fly via Mexico as the route was not so aerodynamically rough and at considerably less altitude. Sellers refused to permit it. As the _Macon_ encountered particularly severe vertical gusts over Texas, two diagonal girders broke and another buckled on the port side where the tail fin was attached to the hull. Repairs were carried out when the airship reached its base, and, after some study by the Bureau of Aeronautics and Goodyear-Zeppelin, it was decided to reinforce that area; however, the work was not considered urgent and was not to interfere with operating schedules.[35]

After taking the _Macon_ back to California to participate in more fleet exercises, the cautious Dresel was replaced on July 11, 1934, by Lieutenant Commander

Herbert V. Wiley (the only officer survivor of the Akron disaster). Wiley made much progress in restoring some of the value to the operations of the Macon by developing it into a sophisticated weapons system operating on a strategic basis. Unfortunately, however, not enough progress was made in installing the reinforcements that had arrived in September of the previous year when the Macon set out on February 11, 1935. Returning to its base at 7:10 P.M. on the next day, off Point Sur, California, the Macon was struck by a gust and lurched violently to starboard. The upper fin tore free taking the upper part of the ring at that point with it. As the fin disintegrated, it punctured the three sternmost gas cells, which emptied almost at once. Upon receiving this news, the personnel in the control car dumped an excessive amount of ballast, causing the Macon to rise well above its pressure height. The helium lost made the airship no longer buoyant, and it descended into the sea. In contrast to the wreck of the Akron, only two lives were lost of the 83 aboard.

The plume of smoke arising from the spot where the Macon had gone down symbolically marked the end of American military interest in rigid airships. To be sure, from time to time (even as late as 1942 in the United States) there were proposals for building new, bigger, and better airships, especially for naval purposes, but they were

never implemented. While it is true that the rigid airship had never really been given the opportunity to prove itself, it was never able (anymore than in Britain) to obtain for itself a high priority in the needs of American society.

Japan

Japan's postwar experience can be dealt with in a few words. As warspoils it received the _L 37_. Because the Japanese had no hangar large enough to house it until the Schütte-Lanz Jüterbog hangar was dismantled, shipped to Japan, and reassembled, the airship was left disassembled upon its arrival in Japan in 1921. By then (1921) Japan's interest in reconstructing the _L 37_ had dissipated. For strike power, the Imperial Japanese Navy had opted for heavier-than-air craft. For reconnaissance, it relied upon its large cruiser force. The upshot of postwar Japanese experience is that the _L 37_ was never reassembled. Despite all that might be taking place elsewhere in the world, neither the Japanese Army nor the Navy showed any enthusiasm for the dirigible airship.

Although postwar military experience with rigid airships was in some respects quite similar in Britain, France, and the United States, in other respects there were marked differences. One area of difference was the motivation behind the inception and continuation of the military airships programs of each country. In Britain it had largely been the wartime challenge to the maritime supremacy of the Royal Navy (presented by the reconnaissance activities of German airships) that caused the British to respond with their own airship program. The French military had had a long-standing interest in airships, but it was the availability of the confiscated German craft that made their postwar program possible and directed the course it followed. Prompting United States efforts was the need to solve the problem of conducting reconnaissance on two oceans. Time and again, this is a thread which keeps reappearing in postwar American discussions.

There are other postwar differences to record. Once the British and the French experienced their separate airship disasters, enthusiasm quickly waned. The United States Navy, on the other hand, persisted for 16 years in its attempts to improve and use the rigid airship. Only after the fourth failure did the United States give up. Moreover, the American naval airships to an extent that was not true of other nations were meant to operate with

the fleet and to be serviced by it. The last two airships were actually flying aircraft carriers, capable of receiving airplanes as well as launching them.

The distinguishing feature of American naval airships was, of course, the use of inert helium as the lifting gas. It could not have failed to be of some mental reassurance to those who flew on board the American craft to know that one of the greatest dangers to prewar and wartime airship crews had been eliminated. Its high cost and general scarcity made its use outside the United States impractical. Yet, while the lives of many aboard the Shenandoah and the Macon were saved because these airships were inflated with helium, its use had not prevented the loss of these airships as well as the Akron.

On the whole, it is probably the similarities (rather than the dissimilarities) in the experiences of the postwar military rigid airship programs of these three countries that are the most striking. For example, in all three it was the biggest, the best, and the most promising airship that crashed or blew up. Tardier in one country than another, it was these disasters that determined the fate of other airships. In all countries these major disasters meant the death of the principal supporters of airship development: Maitland in Britain, du Plessis in France, Strasser and Lehmann in Germany, and Lansdowne and Moffet in the United States.

The ultimate reason for the cessation of military rigid airship programs in Britain, France, and the United States was government refusal to provide more money. When an answer is sought as to why three different governments took this course of action we can only reply (even allowing for national enthusiasms or their absence) that no government was prepared to go on subsidizing a transport system that was technologically (to the point of repeated disaster) inferior. The airship was not forsaken simply because it was too expensive; the reason, rather, was that the promising potential was always just around the technological corner while public reaction to aerial disasters (to which politicians were sensitive) was immediate.

NOTES

1. Robinson, _Giants_, p. 350.

2. Jean du Plessis de Grenedan, _Les grands dirigeables dans la paix et dans la guerre_ (Paris: Plon-Nourrit et Cie., 1925), pp. 8-15.

3. _Ibid._, p. 250.

4. _Ibid._

5. _Ibid._, p. 23.

6. The previous endurance record was set by the _R 34_ while crossing the Atlantic westward in July, 1919 (108 hours, 12 minutes).

7. du Plessis, _Les grands_, pp. 257-65.

8. Fournier, Touchard, Le Bris, and Fayolle, "Le tragique voyage du _Dixmude_," _L'Aerophile_, Vol. XXXII, Nos. 3-4 (February 1-15, 1924), p. 68.

9. _Ibid._, p. 66.

10. _Ibid._, p. 68.

11. Great Britain, Air Ministry, Aeronautical Research Committee, Accidents Investigation Sub-Committee, _Report on the Accident to H. M. Airship R 38_ (January, 1922) in _Reports and Memoranda_, #775 (London: HMSO, May, 1922), Appendix II, p. 17.

12. Fulton, "Rigid Airships," p. 1720.

13. Great Britain, Air Ministry, Accidents Investigation Sub-Committee, _Report on R 38_, Appendix II, pp. 17-8.

14. _Ibid._, p. 12.

15. Campbell attributed the girder failure to "the slipstream of the forward aircrews . . . ," _Ibid._, p. 19.

16. _Ibid._, p. 14.

17. Z was the designation for all naval airships; R meant rigid; and S, scout.

18. _An Act Making Appropriations for the Naval Service for the Fiscal Year Enging June 30, 1920, and for Other Purposes_, _Statutes at Large_, Vol. XLI, Ch. 9 (1919-21), p. 133.

19. Charles L. Keller, "The Hensley Affair," _Journal of the American Aviation Historical Society_, Vol. X, No. 4 (Winter, 1965), p. 282.

20. Letter, "Newton D. Baker, Secretary of War, to Josephus Daniels, Secretary of the Navy," June 17, 1920, National Archives, Record Group 72, Chief of Naval Operations Files.

21. Clifford W. Seibel, _Helium, Child of the Sun_ (Lawrence, Kansas: University Press of Kansas, 1969), pp. 20-5.

22. United States Navy, Bureau of Aeronautics, "Constructive Recommendations by _Shenandoah_ Court," _U. S. Air Services_, Vol. XI, No. 2 (February, 1926), p. 47.

23. Charles L. Keller, _U.S.S. Shenandoah_ (Boston: Commonwealth Publishing Co., 1965), p. 11.

24. "Constructive Recommendations," p. 49.

25. Ibid., p. 48.

26. Whether the United States was to receive two or three of the German airships has been debated, with documentation supporting both sides.

27. United States, Department of State, Telegram, "The Ambassador in France (Herrick) to the Secretary of State, December 16, 1921," document no. 811.348Z 4/90, _Papers Relating to the Foreign Relations_, Vol. II, 1936.

28. Charles E. Rosendahl, "U.S.S. Los Angeles," U. S. Naval Institute _Proceedings_, Vol. LVII, No. 6 (June, 1931), p. 754.

29. David S. Ingalls, "Afterword," in Paul W. Litchfield, _The Story of the Airship_ (n.p. [Akron, Ohio]: n.p., n.d.), p. 71.

30. William A. Moffett, "Rigid Airship Development and the U.S.S. Akron," _National Aeronautic Magazine_, Vol. X, No. 1 (January, 1932), p. 7.

31. Litchfield, _The Story_, p. 25.

32. _Ibid._, p. 16.

3. The probability of the cause of the loss of the airship is backed by this evidence as it is rather unlikely that the surface of the ocean could be seen from 300 feet in a storm.

34. Richard K. Smith, _The Airships Akron and Macon_ (Annapolis, Md.: U.S. Naval Institute, 1965), p. 125.

35. A remarkable order, in view of what had gone before.

CHAPTER VIII

THE PLACE OF THE AIRSHIP IN POSTWAR COMMERCIAL AVIATION

Germany

We have already told how DELAG, the airline of the Zeppelin Foundation (under the direction of Baron von Gemmingen, the nephew and heir of Count von Zeppelin) was revived for passenger service within Germany after the war. In the belief that postwar conditions would be similar to those existing before the war, the Bodensee was put into service on August 24, 1919.[1] After a successful season, the company built the Nordstern with the intention of using it the following year. The Interallied Control Commission, however, put an end to these plans when in 1920 it confiscated the two airships as partial compensation for the six German naval airships destroyed by their crews in 1919. This action, coupled with the provisions of Article 201 of the Versailles Treaty, and the additional restrictions imposed by the London Resolution of May 5, 1921, made a revival of commercial airship service in Germany unlikely.[2]

By 1924 Eckener had become so discouraged about the prospects of reviving the Luftschiffbau Zeppelin in Germany that he transferred all North American rights to Zeppelin patents to a newly formed U. S. Goodyear-Zeppelin Company. He even sent key engineering personnel to work with the new American company. The building of the LZ 126 (the Los Angeles) and its delivery to the United States via trans-atlantic flight, however, brought Eckener and the Zeppelin Company to the public's attention once again. The problem was how to convert a growing interest into money; for the Company was as impoverished as the Weimar government.[3] The only possibility was that the German people might rise to the occasion again as they had done after the Echterdingen disaster 16 years before. Believing that they should be put to the test, he proceeded to organize the "Zeppelin-Eckener Fund." In this he was joined by several of the wartime airship captains. Together they made their appeal through a series of speaking tours across Germany. In two years they had raised 2,500,000 M., enough to begin construction of a new airship. On October 16, 1925, the Locarno Treaty paved the way for the abolition of restrictions on rigid airship size.[4]

By now, Eckener knew that size was the key to success in a commercial airship. The German phoenix he now proceeded to build, the LZ 127, which became the most

successful rigid airship of all, was designed to be as large as the construction shed at Friedrichshafen would permit. Completed in 1928 it measured 775 feet in length and 100 feet in diameter, with an overall maximum height of 110 feet. There were 28 longitudinal girders and 16 diamond truss main rings with two intermediate rings between each pair of these. The 17 gas cells contained 3,037,000 cubic feet of hydrogen, giving it a useful lift of 33 tons, and 12 fuel cells held 918,000 cubic feet of "Blau gas" (similar to propane and of the same density as air) as fuel for the five engines. A gangway between the two types of cells gave access to the valves. The engines were improved versions of the Maybachs used in the _LZ 126_: they produced 550 horsepower and a top speed of 80 miles per hour.

Passenger accommodations were provided in the large gondola (98.5 feet by 20 feet) located beneath the hull well forward. The bow of this gondola also housed the control room. The 20 passengers were housed in 10 staterooms separated from the control room by a lounge and the galley and the radio room.

Countess Hella von Brandenstein-Zeppelin, the daughter of the deceased Count, named the _LZ 127_ as the _Graf Zeppelin_ on July 8, 1928, but the airship was not completed until September 18. An endurance trial flight of 34.5

hours on October 2-3 took the _Graf Zeppelin_ north to Holland and then over the English coast. The flight generated a political controversy: the French claimed it flew over the occupied Rhineland while the Berlin government protested that Eckener crossed Holland to pay his respects to ex-Kaiser Wilhelm at Doorn.

In the course of its total flying time of 13,000 hours (1928 to 1937) and total distance covered of 1,060,000 miles (most of it without incident) the _LZ 127_ became a symbol of pride for the German people. Public subscription provided the bulk of its funding, and Eckener was lionized as the Count had been earlier.

Yet public subscriptions, while they might put the _Graf Zeppelin_ in the air, could not finance the kind of development that Eckener wanted. The _Graf Zeppelin_ was really too small to be profitable on a regular transatlantic flight schedule. Much bigger craft were needed. The problem was how to find the necessary capital, especially as both private capital and government showed no interest in his costly projects. The answer, as he saw it was to dramatize the success of this form of transport. He decided that the _Graf Zeppelin_ should fly around the world. Securing the backing of William Randolph Hearst (the newspaper magnate) for $100,000, which covered about half the cost of the proposed flight, he obtained the

remainder of the necessary funds from German newspaper publishers and stamp collectors (who eagerly paid fees to send stamped envelopes on the trip).[5] Lakehurst, New Jersey, was to be the termini for this flight; intermediate destinations were Friedrichshafen, Tokyo, and Los Angeles. The flight was a complete success. Although the journey lasted 22 days (August 7-29), the actual flying time was only 12 days. Eckener took the Graf Zeppelin back to Friedrichshafen on September 4.

This was the first of Eckener's publicity flights. Others took the Graf Zeppelin on a "triangular" flight to South America and then to Lakehurst before returning to Friedrichshafen (1930), above the Arctic in 1931, and to the Chicago Century of Progress Exhibition in 1933. The Graf Zeppelin began regularly scheduled service to South America in 1932. On November 24, 1935, it inadvertently almost broke the endurance record of du Plessis' Dixmude. Unable to land at Pernambuco (its terminus in Brazil) while a revolution was in progress there, it spent 118.7 hours in the air.[6]

As a result of this publicity the German Government increasingly warmed to Eckener's proposal to build the ideal transatlantic passenger airship. An enlarged construction shed was built with government funding in 1929-30. Construction of the airship (financed partly by the

Luftschiffbau and partly by the government) began in the fall of 1931. The original design for the airship (to be called the Hindenburg) provided a capacity of 5,307,000 cubic feet of hydrogen in a frame 761 feet long and 128 feet in diameter. This plan was abandoned, however, when the British R 101 crashed and burned on October 5, 1930, and a new design was drawn up to provide the same performance as projected for the former design but using helium as the lifting gas.

The new design provided for a hull measuring 803.8 feet long and 135.1 feet in diameter; the gas volume was 7,062,100 cubic feet. Thirty-six triangular girders held the 15 transverse main rings in place. Between each of these main rings, two unbraced intermediate rings provided stability for the hull. Four engine gondolas were suspended in pairs amidships and aft; in each of these was a 16 cylinder Daimler-Benz diesel producing 1320 horsepower. The control car was beneath the hull forward while the passenger quarters were in two decks somewhat forward of amidships, entirely within the hull. Included in these accommodations was a pressurized smoking room, an aluminum baby grand piano, and a well-stocked wine "cellar."

Unlike earlier products of Luftschiffbau Zeppelin, the exhaust valves on the gas cells of the Hindenburg were deep within the hull rather than at the bottom of the cells.

Originally, Eckener planned on incorporating ballonets of hydrogen within the helium cells to be valved off to offset weight loss during a flight. The helium supply was restricted to the United States by the Helium Control Act of 1927, however, and the gas cells of the Hindenburg had to be filled with hydrogen.[7] The ballonets, already in place when Eckener learned that helium would not be available for purchase, were removed, but the valves could not be changed and the hydrogen valved into exhaust shafts (the longest of these was 70 feet) just above the axial gangway.

The construction of the Hindenburg, undertaken in a period of economic depression, was completed only with the help of the German National Socialists, who recognized the propaganda value of a giant airship. Joseph Goebbels, the Propaganda Minister of the Hitler regime that had come to power in January, 1933, contributed 2,000,000 M. Field Marshal Hermann Goering, jealous of his position as Air Minister, provided another 9,000,000 M. to finish the airship. To bring the operations of the Luftschiffbau under state control, Goering formed the Deutsche Zeppelin Reederei, a German national air line with the Luftschiffbau as a junior partner. Control of operations was taken from Eckener (who constantly criticized the misuse of his airships) and given to Eckener's second-in-command, the more malleable and strictly apolitical Ernst A. Lehmann.

On March 4, 1936, the _Hindenburg_ made its first test flight. With large swastika pennants emblazoned on its tail fins (these were required on the _Graf Zeppelin_ also after October, 1933) the new airship became one of the showpieces of the Third Reich. In March, 1936, it was used for several propaganda flights in connection with Hitler's abrogation of the Locarno Treaty and the occupation of the Rhineland. During the rest of 1936 the _Hindenburg_ was in almost continuous use, either for further propaganda purposes (flights over the Berlin Olympics, for example) or on trips to Lakehurst, New Jersey, or Rio de Janeiro.

New facilities at Frankfurt-am-Main provided a better departure point than Friedrichshafen because airships could carry a greater load on departure. So successful was the _Hindenburg_ considered to be to the Third Reich that a new airship, virtually a copy of the _Hindenburg_, was begun at Friedrichshafen on June 27, 1936. It was to be the _LZ 130 Graf Zeppelin II_, scheduled to begin service in August, 1937.

However, as the checkered career of the airship might have warned, that was not to be. On May 6, 1937, as the _Hindenburg_ was completing its first flight of the year to Lakehurst, New Jersey, it exploded and sank to the ground in flames. Every ghastly detail of this terrible disaster

was broadcast to the American public. The cause of the fire that was first seen inside the hull near the tail has never really been determined. Some thought the disaster sprang from the electrical storm that was in the vicinity as the airship maneuvered close to the mooring mast. Eckener believed a bracing wire snapped during landing maneuvers and ripped open a gas cell, which permitted hydrogen to leak out where it could be ignited by a discharge of static electricity (St. Elmo's fire). Commander Garland Fulton, a United States Navy airship expert, theorized that the electrical discharge from the storm ignited hydrogen in the long ventilating shafts of the Hindenburg.[8] Captain Lehmann (the director of the Luftschiffbau), who died of his burns from the fire, concluded that it was sabotage.[9] Commander Charles Rosendahl, in command of the naval air station at Lakehurst, substantially agreed with him. Two authors have written books, both of a highly speculative nature, purporting to demonstrate that sabotage is the explanation and blaming one of the crewmen who died in the fire.[10] Yet the possibility of sabotage was never explored by the American and German investigation commissions. Neither commission was drawn to a cause that might have embarrassed their governments. Perhaps the heightened political tension of the times helps to explain this.[11]

Whatever the cause of the disaster, it sealed the fate of the rigid airship. It did for the Germans what the disaster of the *R 101* did for the British. It was purposeless to point out that while 35 (including only 13 passengers) had died, 62 had survived. The psychological damage was complete. The *Hindenburg* ranks with the *Titanic* as as one of two great transport disasters. The old *Graf Zeppelin* was turned into a museum while the new airship (*Graf Zeppelin* II), completed and first flown on September 14, 1938, was primarily used by the Luftwaffe to spy on the British defenses before the outbreak of the Second World War.[12] At the order of Goering, who needed the metal for aircraft production, both airships were dismantled by Luftwaffe construction crews in the early spring of 1940. The hangars at Frankfurt were demolished in May on the pretext that they blocked the runway for German bombers operating over France.

Britain

In Britain, the postwar interest in civil airships centered initially around the Air Ministry where its Director of Airships, Commodore Maitland, actively promoted

their commercial adoption. A statement issued by the Air Ministry as early as January, 1919, emphasized the advantages of the airship as a "long-distance weight-carrying craft" and noted that it was "worthy of consideration for commercial flights over sea or land . . . and on journeys involving non-stop flights of 1,000 miles and upwards."[13] It even set forth transoceanic traffic with airplane connections at both termini as being most probably successful, and provided tables of comparative figures for performance of airships and airplanes and the costs involved in establishing and maintaining such an airship line. The impending dismantling of the British Admiralty's airship program and the subsequent availability of both bases and certain airships was also alluded to in this report.

With Major G. H. Scott, another airship promoter in the Air Ministry, Maitland sought publicity on a wide scale. On April 21, 1920, he addressed the Royal Society of Arts on "The Commercial Future of the Airship," for example.

The zenith of Maitland's attempts to promote commercial interest in the airship was the round trip passage of the British R 34 across the North Atlantic in July, 1919. Such a flight had been discussed in the British Ministry early in March when tentative proposals had been made by a steamship line (Cunard) and two engineering firms (Armstrong-Whitworth and Beardmore) for a commercial transatlantic airship service. The essential prerequisite

was a successful demonstration of the feasibility of such a flight. Eventually, it was decided by the Air Ministry that the R 34 should make the voyage. It was hoped that this flight would help to investigate the conditions prevailing in the North Atlantic, demonstrate the capabilities of the airship, and "forge a new link, by way of the air," between Britain and the United States.[14] As we know from earlier pages, the R 34 succeeded in all these tasks; it successfully made the first round trip across the Atlantic by air; and having done so it was largely ignored. Such is fate.

Lack of interest, lack of money, and the wreck of the R 38 in August, 1921, also caused the demise of a proposal that had been made to the Imperial Conference in 1921 that six wartime rigid airships be "converted" to civilian use for a route connecting Britain with New Zealand via Cairo, India, Singapore, and Australia. However the project was resurrected the following year (1922). It was proposed that the government subsidize the construction of five rigid airships by the Airship Guarantee Company (a Vickers subsidiary) to be used in a biweekly flight to India, and later, a weekly flight to Australia. It was not until the Labour Party took office in January, 1924, that the program was given its final shape, principally at the hands of Lord Thompson, the Labour Air Minister and a

supporter of airships. Rather than the five airships proposed earlier, there were to be only two. One of these was to be constructed by the Airship Guarantee Company (the R 100), but the other (the R 101) was to be built by the Royal Airship Works.

Both airships were to be built to the same specifications: gas capacity of 5,000,000 cubic feet; maximum speed of not less than 70 miles per hour with a cruising speed of at least 63 miles per hour; full accommodations for 100 passengers; and a gross lift (under standard conditions) of 150 tons with a structural weight of not more than 90 tons, giving a useful lift of 60 tons. Moreover, the engines were to run on a fuel that "could safely be carried and used in sub-tropical or tropical climates," apparently under the impression that gasoline was excessively dangerous at the higher range of temperatures.[15] In effect, this meant the use of diesel engines despite their weight and the lack of any previous experience with them in aircraft.

Barnes Wallis, who headed the design team for the R 100 (and who had previously designed the R 80), however, refused to have anything to do with diesels, and, after experiments with kerosene and hydrogen burning engines proved unsatisfactory, he opted for six rebuilt Rolls-Royce Condor engines of 660 horsepower each. The Air Ministry

accepted the substitution and planned to use this airship on a route to Canada. Wallis kept the number of structural members in the R 100 to an absolute minimum. The hull, 709 feet long and 133 feet in diameter, had but 16 longitudinals and 15 transverse frames, all of deep duralumin tubing girders, with no intermediates.[16] The radial wiring of the transverse rings was braced to an axial girder that extended from the bow to the stern. The 15 gas cells enclosed were made in Germany by B. G. Textilwerke, a Zeppelin subsidiary. Beneath the gas cells and forward but still within the hull were the passenger accommodations in three decks, all with windows in the outer cover. The lowest deck was for the crew while the upper two housed the passenger berths, the dining salon, and a short promenade deck. Suspended beneath the lowest deck and attached to the hull was the control car, which was about 50 feet long. The six engines were paired back to back in three engine gondolas, two of which were suspended to port and starboard amidships while the third was aft under the keel.

Because of the structural failure of the R 38 above the Humber River in Britain in August, 1921, an Airship Stressing Panel had been set up the following year to continue the line of investigation earlier made by the National Physical Laboratory with the R 32 into the

calculation of aerodynamic loads during maneuvers at speed. The designs of the two airships authorized in 1924 were to incorporate the recommendations made by this panel. In addition, they were to be inspected by an independent official agency, the Airworthiness of Airships Panel, which was empowered to deny a commercial license to any airship that did not meet its minimum strength requirements.[17] The old R 33, laid up in 1921, was refurbished to be used in conducting more tests, but subsequent damage limited its usefulness. (It was subsequently dismantled in May, 1928.)

Although design work in connection with the R 100 and the R 101 had commenced in 1924, the extensive delays in testing, the bickering and jealousy between the government design team and the Wallis group, and the somewhat unreliable political atmosphere worked against completion of either airship. The R 100 made its first flight on December 16, 1929. Its trials revealed that its weight (105 tons) exceeded the contract specifications of 90 tons; but the gross lift somewhat compensated for this by surpassing the 150 ton requirement by 6 tons. The top speed was 81 miles per hour.

The R 100 was required by the government to demonstrate its airworthiness by an actual intercontinental flight. After minor modifications resulting from previous test

flights, it departed for Canada on July 29, 1930. The journey was relatively uneventful except for damage to the three-year-old linen outer cover incurred in a squall, and some minor troubles experienced with the rebuilt engines. The airship was moored at St. Hubert on August 1. A short flight on August 10-11 carried Canadian officials on a sightseeing tour, and then on August 14, the R 100 returned to Cardington, England, on August 16.

The leader of the government's design team for its other airship, the R 101, was Lieutenant-Colonel V. C. Richmond. Although an experienced constructor of non-rigids, he had no previous experience with rigids; consequently, he acquiesced to the incorporation of impractical devices at the insistence of his superiors, including the heavy diesel engines. As the design team was determined to make the R 101 as safe as possible, extensive costly tests were conducted on virtually every feature of the structure.[18]

The resulting design was fully streamlined and 732 feet long with a maximum diameter of 132 feet. The structural failure of the R 38 influenced Richmond to abandon the almost universally used duralumin in favor of stainless steel for the 15 main longitudinals and the 15 main rings. The 11 largest rings were of a novel design with a large triangular cross section and no transverse bulkhead bracing:

unfortunately, these rings took up space that otherwise would have been occupied by gas cells and did nothing to impede longitudinal shifting of the gas bags which instead were held in place by lashings.

Some features of the airship contributed significantly to its being over the specified weight of 90 tons by some 23 tons: the steel hull and its ring structure; the five Beardmore railroad diesel engines, each weighing 2.35 tons; and the restricted gas cells with valves mounted on their sides that opened when the vessel rolled more than three degrees. Tests after inflation in July, 1929, revealed that the 4,998,000 cubic feet of gas provided a useful lift of only 31.5 tons. An extra bay added in the summer of 1930 alleviated the problem somewhat as did loosening the cords restricting the gas cells. The latter expedient, however, allowed the bags to surge forward and aft causing the R 101 occasionally to dive at an angle of up to 25 degrees. The esthetically pleasing rakish tail fins were ineffective at low speed and the sluggishly heavy airship responded slowly even to full elevator. The problem was exacerbated by the tendency of the moving gas cells to have holes scraped in them when they rubbed against the framework.[19]

At the urging of Lord Thomson (the Air Minister) the addition of the extra bay (with 510,300 cubic feet of gas,

which brought the useful lift to 49.3 tons) was hastily completed in late September and the airship was brought out on October 1, 1930. After a short test flight, Lord Thomson insisted on an immediate trial acceptance flight to India in which he would be a passenger.[20] At 6:36 P.M. on October 4 the R 101 left the mast and ascended to 1,500 feet, well over its pressure height. The weight gain from the loss of gas was compounded by the addition of water on the hull as a result of the rain. Fighting a head wind across the English Channel the R 101 passed Beauvais in France at 2:00 A.M. on October 5 at a low altitude. A few minutes later a long steep descent was corrected momentarily, but the airship went into a second dive that took it bow first onto a French hillside where it burst into flames. Most of those aboard, including Lord Thomson, perished. The tragedy was reported on the first BBC news of the day and its effect in Britain was electric. Henceforth, no good word could be heard in Britain for the rigid airship.

The British Court of Inquiry, limited by the lack of evidence, and with few surviving witnesses, never did decide on the precise cause of the crash. Its report, however, hinted that there had been a rapid and critical deflation of a forward gas cell.[21] Despite recommendations of the Court of Inquiry for further tests, nothing was

done. The idea of Imperial communication by airship was dead. The report was pigeon-holed; the Court of Inquiry's files were put away; so far as Britain was concerned that was the end of its adventures in airship travel.[22] The remaining R 100 was broken up in 1931.

United States

Attempts to promote commercial rigid airship interest in the United States in these years found many who were willing to listen but almost no one who was willing to act. Few magazines or periodicals of the '20's and '30's (especially those concerned with aeronautics) did not run some articles that advocated the use of rigid airships for commercial purposes.[23] In 1926, the United States Congress enacted legislation to provide a regulated basis to encourage the development of commercial lines.[24] Paul W. Litchfield (the president of Goodyear Rubber Company), in anticipation of commercial, as well as military, interest in rigid airships, formed the Goodyear-Zeppelin Corporation and bought the North American rights to the Zeppelin patents.

With these exceptions, no American entrepreneur attempted to exploit the postwar potentialities of

commercial rigid airship transport. A number of factors may be said to have contributed to this attitude: the sums required were large; there were no pre-existing airship facilities (the prerequisite hangars, mooring masts, and servicing structures did not exist); the airship might threaten existing investment in other forms of transport; and most important of all was the supposed low profitability of the industry. Money could be better invested elsewhere. The basic problem was not the shortage of money or entrepreneurs but the fact that the airship industry was still technically unsound. No American was going to put sums of this scale in an industry overshadowed by disaster. Had the sums required been smaller and the disasters less catastrophic the industry in America might have taken an entirely different course than it did.

The disasters of the R 101 and particularly the Hindenburg closed a chapter in airship history. Temporarily, at least, the age of the rigid airship was over. Yet the disasters that ended the British and German civil airship programs pointed up that, except for the use of highly explosive hydrogen, the airship was a remarkably

safe vehicle when properly designed. Neither the crash of the R 101 nor the conflagration of the Hindenburg would have caused serious injury if the airships had been able to use helium. The fundamental flaw of the airships was technical. It was a flaw that until recent years was to prove its constant undoing.

Perhaps it all boils down to the fact that there has been no other form of transport that so dramatized its technical shortcomings as the airship did. All things considered, the rigid airship was no less safe, no less economical, than, say, earlier steam transport on land and water, or the airplane industry that grew alongside it. But what the public saw in all great airship disasters was blazing infernos, and against that, logic could not prevail. Moreover, the airship not only exhibited its troubles: it concentrated them. Its disasters were always of major proportions. Had the airplane not been available, perhaps the airship industry would have grown regardless of its recurring disasters (as Mississippi steamshipping did); but that is not the course events took.

NOTES

1. Colsman, Luftschiff, p. 318.

2. United States, Department of State, "Resolution of the Supreme Court Council of the Allied Powers, London, May 5 1921," document no. 462.00 R 29/762, Papers Relating to the Foreign Relations of the United States, 1921, Vol. II (Washington: United States Government Printing Office, 1936).

3. Eckener, Im Zeppelin, p. 98.

4. Great Britain, Parliament, Parliamentary Papers (House of Commons & Command), 1924-5, Vol. XXXI (Accounts & Papers, Vol. 16), Cmd. 2525, "Final Protocol of the Locarno Conference, 1925 (and Annexes) together with Treaties between France and Poland, and France and Czechoslovakia," p. 573.

5. Stamp collectors partially financed many of the Graf Zeppelin flights.

6. Lehmann, Auf Luftpatrouille, p. 34.

7. An Act To Amend the Act entitled "An Act authorizing the conservation, production, and exploitation of helium gas, a mineral resource pertaining to the national defense and to the development of commercial aeronautics, and for other purposes," Statutes at Large, Vol. XLIV, Part II, Chapter 355 (1925-7).

8. He was an eyewitness to the disaster. As cited in Douglas H. Robinson, LZ 129 Hindenburg (New York: Arco Publishing Co., 1964), p. 31.

9. Charles Rosendahl, What About the Airship? (New York: Charles Scribner's Sons, 1938), p. 25.

10. A. A. Hoehling, Who Destroyed the Hindenburg? (Boston: Little, Brown & Co., 1962) and Michael Mooney, The Hindenburg (New York: Dodd, Mead & Co., 1972).

11. German rearmament, occupation of the Rhineland, and the mistreatment of Jews were causing unfavorable American reactions.

12. The British radar failed to find the airship on at least one trip up the Channel.

13. Great Britain, Air Ministry, "Airships for Commercial Purposes," Flight, Vol. XI (January 30, 1919), p. 144.

14. Patrick Abbott, Airship (New York: Charles Scribner's Sons, 1973), p. 70.

15. Nevil Shute [Nevil Shute Norway], Slide Rule: The Autobiography of an Engineer (New York: Ballantine Books, 1954), pp. 71-2.

16. The girders were 27 inches deep and made of tubing rather than triangular members.

17. Higham, British, pp. 262-3.

18. Two years were spent testing just the hull and fin structure design.

19. This problem was alleviated somewhat ineffectually by the addition of 4,000 pads to the points of contact.

20. Great Britain, Air Ministry, Report of the R 101 Inquiry (London: HMSO, 1931), p. 67.

21. Ibid., p. 126.

22. A design for an R 102 was drawn up but ignored.

23. For example, Karl Arnstein, "Why Airships?" U.S. Air Services, Vol. XVII, No. 12 (December, 1932), pp. 27-8 and "The Commercial Possibilities of the Airship," The Engineer, Vol. CL, No. 3892 (August 15, 1930), pp. 175-6.

24. Air Commerce Act of 1926, Statutes at Large, XLIV, Part II, Chapter 344 (1925-7).

CHAPTER IX

CONCLUSIONS

As an invention, the rigid airship had a relatively short life span, from 1900 to 1940. Excluding the first years of experimental development, its period of utility as a branch of transport was some 10 years shorter. Yet it was an invention which provided a nearly ideal blend of great range and high load capacity long before any other form of air transport was able to compete with it.[1]

That the rigid airship of Count von Zeppelin was not the only technological response based on accumulated knowledge to the challenging problem of flight is clearly illustrated by the large number of other similar and dissimilar inventions produced in the first decade of the 20th century alone. Among others were the Wright Brothers' airplane (1903); the Langley Aerodrome (1903); the Santos-Dumont non-rigid airships and airplanes (1900-10); the Wellman non-rigid airship _America_ (1910); the Tsiolkovskii metal hull airship (proposed circa 1900); and the British H.M.A. _No. 1_, known as the _Mayfly_ (begun in 1909).

It is interesting to note that all of these, except for the Langley Aerodrome and the Tsiolkovskii proposal, were the results of the work of empiricists who had little scientific background. Even to a more extreme degree this was also true of the rigid airship. Zeppelin had no engineering background; instead, he hired engineers to put his ideas into shape. Eckener was even more of an amateur; as a journalist with a doctorate in economics, he was a complete novice in the field of aerodynamic theory. Yet these two men were primarily responsible for the invention and initial success of the rigid airship.

As with the Wright Brothers (as well as with such 19th century predecessors as Giffard and the Tissandier Brothers) Count von Zeppelin was plagued by the need for capital. His problem was compounded by the fact, that, of necessity, a rigid airship had to be large and therefore costly. At first it was the indefatigable Count, who risked his entire personal fortune on the enterprise; later, it was Eckener, who was able to use his journalistic skills to arouse the public's interest in financing further developments. While lukewarm military interest all but closed the coffers of the state (the usual source of financial wherewithal in Imperial Germany), and Zeppelin's efforts to interest the leading public figures of the day failed, it was Eckener, the "entrepreneur" of the

airship, who succeeded in using his journalistic skills to link Count von Zeppelin's invention to German national pride. He was not only able to provide the widest possible dissemination of the news of the Count's activities; he also knew how to appeal to the German's patriotic sense. Thus did the rigid airship become the only major transport invention financed by public contributions. And contrary to all the expectations of Zeppelin, it was the German public that used it. Between June 28, 1910, and August 7, 1914, more than 10,000 passengers were carried on nearly 1,600 flights.

In contrast to these private efforts, the interest of German military leaders in the rigid airship increased significantly only after the carefully formulated plans for rapid victory in the First World War went awry. Only then, in response to military demand and with the State's money, did the production facilities of the Luftschiffbau Zeppelin expand rapidly. The obstacle provided by the patents held by the rival Luftschiffbau Schütte-Lanz was soon overcome, permitting a more rapid development than might have been possible. Yet, as we have tried to show in these pages, despite the support of the military and the continuous improvements in airship design and performance, the speed, size, and relative vulnerability (to enemy fire) of the airship placed it at

a disadvantage when compared with the airplane. So far as warfare is concerned, it was the misfortune of this invention that it should have been developed concurrent with the faster fixed-wing aerodynamic craft. Because of this, the German Army curtailed and then abolished its airship program in 1917, leaving only the Naval Airship Division active. By the end of the War, the rigid airship had become discredited as a military device except for reconnaissance at sea.

The process of diffusion of airship technology that began shortly before the War (and was greatly accelerated by it) followed a textbook pattern of technological diffusion from a single point: in this case, Germany. The process culminated at Versailles where the victorious Powers divided the remnant of the German naval airship fleet among themselves. However, once other countries such as Britain and the United States had begun airship programs of their own, the technological bases of these programs developed increasingly independently of each other (in Britain even the private firm building the R 100 and the Air Ministry group working on the R 101 did not exchange information).

Regardless of the source and development of technology, practices in the airship industry often achieved the opposite of what was intended. While the German postwar

commercial transatlantic airships (as well as the British R 100 and R 101) were used primarily for passenger service, that is not what their originators had intended. It was the cargo-carrying attributes of rigid airships that had been stressed in the early days. Yet no such cargo-carrying airships ever reached the drawing board.[2] Cargo obviously was carried on board the passenger airships, but it was always an inconsequential percentage of the total load on any trip. Like the first British railroads, airships were thought to be most advantageous when carrying freight but finished up carrying people.

The explanation for this is manifold. The airships built for commercial use after the mid-1920's were employed where they would prove most profitable at that time: i.e., in passenger service. Passenger service, moreover, was a much better way to expose the virtues of airship travel to investors or shippers. Even if the airships had been intended to carry freight, the likelihood was--consider the introduction of other forms of transport such as the railroads--that the first few trips would have been concerned with carrying those whose interest in the new form of transport had been aroused.

On this score, it is curious that although German entrepreneurs set up a triangular transatlantic passenger service operating from Germany, and the British government

at least attempted to establish a system of imperial communications with the *R 100* and the *R 101*, there were no such moves from the American side. True enough Paul Litchfield of the Goodyear-Zeppelin Corporation in Ohio expected to build more than two rigid airships for the government, yet the movement was largely stillborn.[3] Why would the Germans have sent their best designers to Litchfield's new undertaking in Ohio if they had not been convinced that the United States would become the rigid airship center of the world?

The reluctance of the American entrepreneur to become involved with the airship industry stems from the peculiarly uncertain conditions of the American commercial scene, and partly from the fact that more money could be made from other investments with far less risk. After 1929, the sums needed were simply not available for this kind of investment. Nor were they small. The United States' *Macon* (built in 1934) cost $2,450,000. Helium to inflate it cost $375,000 more. That excludes salaries, ground facilities, and promotion. Moreover, America's competitors did not have to operate on a profit-loss basis. The Deutsche Reederei was heavily subsidized by Goering's Air Ministry. Likewise, the *R 100* and the *R 101* were not built to make money. They were to be part of an imperial system of communications which, had they been developed,

would also have been heavily subsidized. American private enterprise never seems to have had any illusions about the profitability and the risk element of the airship industry.

What we do find, in fact, in the history of this industry is a different situation in each country where the airship was developed. In Germany, Eckener concentrated his efforts on commercial transoceanic airships, utilizing both experienced personnel and extant facilities. German rigid airship developments remained primarily (until the Nazi era) a matter of private enterprise.

In Britain the opposite was true. It was the government that was all-important. Of the three rigid airships begun in postwar Britain, only one (the R 100) was built by a private firm, and it was intended for a government controlled imperial airship line.

As in Britain, so in the United States it was the naval branch of the armed forces that initiated the postwar American airship program and provided the necessary funds to bring the needed production facilities into existence.

Initially, the Americans followed the British practice of copying the Germans, but not for long. While one of the two airships provided for in the American naval program of 1919 was purchased abroad, the other was built by naval

designers and constructors. The American naval designers and engineers soon altered the plans of the L 49 that the French had provided. The subsequent *Shenandoah* was less a copy of the L 49 than the R 34 was of the L 33. The reason why the *Shenandoah* was built by United States naval personnel (in contrast to German and British practice of relying upon private firms) was that no American company had the technological knowledge necessary to produce a rigid airship. It was the formation of the Goodyear-Zeppelin Corporation in 1924 (with a staff of German design engineers and access to all the Luftschiffbau Zeppelin patents) which changed that situation. In 1926, when Congress authorized the acquisition of two new large airships for the navy, interested United States companies were requested to submit proposals and bids. Not surprisingly, U.S. Goodyear-Zeppelin was awarded the contracts.

In this respect the American approach to rigid airship design and construction contrasts with that of the British. Whereas the British had relied almost exclusively on training their own countrymen (moving from mere copies of other people's work to original though conventional designs constructed first by private engineering enterprises and later by government-directed works), the Americans had relied (as they would later with rocketry) on some of the best German design talent. Contrary to Britain's

course they had abandoned governmental airship construction for contracts with private corporations.

Ultimately, it was not the different national approach to the development of this industry that mattered, but the shock of overwhelming disaster. The 1930's were undoubtedly the crucial years determining the industry's fate. When the decade opened the ZR 3 Los Angeles was being used to train the crew for what was seen as the military aircraft of the future, the ZRS 4 Akron, which was under construction at Akron, Ohio. In Britain, the R 100 was being prepared for crossing the Atlantic while the R 101 was being reworked for its upcoming trip to carry the Secretary of State for Air triumphantly to India. In Germany, the Graf Zeppelin had just completed its astounding journey around the world and was being prepared to inaugurate the triangular transatlantic service to South and North America. Plans were also being discussed in Germany for a new and much larger transatlantic airship, tentatively named the Hindenburg. No matter how much the American results might have fallen short of expectations, at long last, the rigid airship was apparently on the verge of assuming its rightful place in distant military and commercial transport. Ten years later not a single rigid airship was left!

What is the meaning of this extraordinary reversal of fates? How is it to be explained? The rigid airship had proved itself relevant to the needs of society for long-distance carriage. In three countries (Germany, Britain, and the United States) it was supported by the State. Except in war, there was no competition from airplanes to speak of. In the 1930's transoceanic clippers were just being introduced. In short, the rigid airship seemed to meet almost every criteria for a successful invention. It failed, however, on one count and that count was fundamental. Technological insufficiency was undoubtedly the Achilles' heel of this industry. No one who studies it can ever disassociate himself from the catastrophes which seem to come one after the other to mar the industry's course.

Of the six rigid airships listed above, three were to crash and two of these three exploded (the British R 101 and the German Hindenburg), while the third (America's Akron) took all but three of its crew and passengers down with it in the Atlantic. One of the other two airships built during the 1930's (America's Macon) also crashed into the sea, but only a few lives were lost. Each disaster was due to a technological fault or shortcoming. The R 101 had so many faults it is difficult to pinpoint the exact cause of its death dive, but it is probable that one

or more forward gas cells, weakened by chafing, gave way. The *Akron* was equipped with only a barometric altimeter--all but totally useless in a storm such as it encountered off the New Jersey coast in 1933. The upper tail fin on the *Macon* was known to be dangerous before it crashed; but evidently it was not considered sufficiently dangerous to interrupt the schedule of flights.[4] The *Hindenburg* was apparently the victim of its gas cell valve locations and long exhaust vents. The fault lay not in human error but in an inadequate technology. The technical shortcomings were made more apparent because, in contrast to the development of other forms of transport, the whole thing was played out on a very narrow front. Everything seemed to depend on a singular success or a singular failure.

Moreover, as we have already implied, the airship captured the people's imagination as few other things have done. It hung in the sky above them. Its successes and its failures were visible. As disaster followed disaster the awe felt by the man on the street turned to revulsion. As it did so, the politicians in America and Britain moved from government sponsorship to government opposition. In Germany, the *Hindenburg* disaster (as we have shown earlier) curtailed Lehmann's plans and prompted an order from the Führer restricting German

airship activity to Germany. The pending German invasion of France in 1940 gave Goering the excuse he needed to demolish not only the airships but also the construction shed at Friedrichshafen. Fourteen years earlier, when some of the postwar doubts were being expressed, a British airship enthusiast had written:

> The airship will stay. Its abandonment is inconceivable . . . no vehicle was ever abandoned before serving its purpose . . . . That is something for the pessimist to think over . . . for this talk of giving up the airship is going to look very childish in just a few years from now.[5]

By 1940, these words had been completely forgotten.

NOTES

1. Not until the 1970's was an airplane (the C5a Galaxy) developed that could lift as much tonnage as the Hindenburg.

2. "The Development of Airship Transport," Aeronautical Engineering, Supplement to The Aeroplane, Vol. XXV, No. 11 (September 12, 1923), pp. 273-4. E. E. H. Evans, "The Development and Future of the Airship," Journal of the Institution of Aeronautical Engineers, Vol. I, No. 5 (May, 1927), p. 53.

3. Paul W. Litchfield, "Establishing an Airship-Building Industry in the United States," U.S. Air Services, Vol. XVII, No. 4 (April, 1932), p. 24.

4. The willful postponement of the repairs can be explained by the officers' confidence in the technological soundness of the airship they were flying.

5. Archibald Black, "Leviathans of the Air," Aero Digest, Vol. VIII, No. 1 (January, 1926), p. 19.

AFTERWORD

The history of the rigid airship in the period from 1900 to 1940 casts light on many aspects of the past. We have tried to show in these pages, for instance, how the airship compared and contrasted with airplanes, how the airship got started, who directed it, the role of the military *versus* that of the public, the interrelationship of State and private enterprise, the changing designs, the diffusion of its technology, the impact of war, the role of the airship as a symbol, and its effect upon the public's imagination. However, none of these aspects, it seems to us, should be stressed as much as this industry's inability to overcome its technical weaknesses. In 40 years (from 1900 to 1940) the rigid airship came into being, had a brief but spectacular career, and then passed out of existence. The cause--according to us--was technological inadequacy. The ironic fact is that every one of its technological weaknesses--such as metal fatigue and gas supply--has been surmounted in the 35 years since the last rigid airship fell victim of the scrapper's torch in 1940.

Even more ironic is the fact that the potential advantages offered by an airship (particularly as a freight carrier) are more relevant now than ever before. In 1973 aircraft carried only .05 per cent of the world cargo tonnage. The great drawback of aerodynamic aircraft is that enlargement of such aircraft increases structural weight far faster than carrying capacity. For the airship, the reverse is true. Moreover, a modern airship could fly in all weathers and would be far more maneuverable than aerodynamic aircraft. The scientific fact is that it is cheaper to move an aerostatically supported load than it is to move the same load supported aerodynamically. The rigid airship offers an energy-conserving alternative to the noise and exhaust pollution of contemporary aircraft. While really high speeds are not practical, for most cargo purposes, 200 to 300 miles per hour is quite sufficient and attainable. The probable motive power will be some form of internal combusion engine, although atomic power units are feasible. An airship with nuclear power would be virtually silent and could stay airborne for several years.

That these things are within the realm of possibility is confirmed by the announcement made by Manchester Liners Ltd. (one of the British firms to pioneer containerized cargo) on November 4, 1970, that a subsidiary, Cargo

Airships Ltd., had been formed to study the feasibility of airship transportation. Their initial concept is of a craft 1,200 feet long capable of lifting 500 tons as a payload and having a top speed of about 100 miles per hour. The researches of this subsidiary revealed that there was indeed economic potential in the plan. A flying prototype to conduct trials is even now nearing completion. Assuming that this airship does not vary greatly from the original proposal of the company, it would utilize at least a semi-monocoque hull, which consists of a stressed outer skin of plastic or light metal that would carry most of the stresses while ring braces, at load-bearing points supported the aerostatic stresses. Such a hull, it has been shown, would be stronger than that of previous rigids yet comparatively easy to mass-produce.

At about the same time, another British company, Airfloat Transport Ltd., initiated a program of study for an airship with a gas capacity of 30,000,000 cubic feet capable of carrying 280 tons over 1,000 miles. The possible difficulties they foresaw involved loading and unloading cargo while simultaneously transferring ballast. As in the Manchester Liners plan, the airship would not land or dock to load or unload cargo; instead, it would hover some 200 feet above while either a winch system or helicopters made the transfer.

A few months before the British firms announced their plans, it was reported from Germany that "a shipping company in Lübeck" had tentative plans to build a nuclear-powered airship designed by an Austrian engineer by the name of Erich von Veress. This airship would have a hull very similar to the rigids of the '30's except that the outer skin would be fireproof plastic. Some indication of the size is given by the expected performance; it is to carry 500 passengers and 50 tons of cargo at a speed of 220 miles per hour. Likewise, for two years the Soviet Union (where a bold airship program proposed in the early '30's materialized into nothing more than a nice set of postage stamps) has reportedly been conducting a study of a very similar but smaller atomically powered airship carrying 100 passengers at speeds of about 150 miles per hour.

Most recently (April 17, 1975), the British Royal Air Force demonstrated at the hangar at Cardington a prototype of an airship that derives its lift from helium sealed in plastic bags (or cells) within its rigid saucer-shaped hull. The diameter of this prototype is only 30 feet and its maximum height is 8 feet, but larger airships of this type could carry cargo and passengers in the central section, which would be proportionately larger.

Despite all the inherent advantages of the rigid airship there is nevertheless one all-important factor that must be overcome before airships can be seen overhead again. That factor is the psychological connection between the rigid airship and fiery disasters--the legacy of three decades of technological failure.

APPENDICES

APPENDIX A

COMPARATIVE STATISTICS ON RIGID AIRSHIPS

Builder's Name	Name or Number	Volume (cu.ft.) 100% Inflated	Length (ft.)	Diameter (ft.)	Gas Cell No.	Useful Lift (lb.)	Total H.P.	First Flight	Trial Speed (m.p.h.)
				Zeppelins (Luftschiffbau Zeppelin G.M.B.H.)					
LZ 1		399,000	420	38.5	17	1,430	28.4	7/2/00	17
LZ 2		366,200	414	38.5	16	6,180	170	11/30/05	25
LZ 3		403,600	414	38.5	16	6,180	170	10/9/06	25
LZ 3	Z I	430,800	440.3	38.5	17	6,400	210	10/21/08	27.8
LZ 4		530,000	446	42.5	17	10,150	210	6/20/08	30
LZ 5	Z II	530,000	446	42.5	17	10,250	210	5/26/09	30
LZ 6		530,000	446	42.5	17	9,700	230	8/25/09	30
LZ 6		565,000	474	42.5	18	9,620	375		35.2
LZ 7	Deutschland	683,000	486	46	18	11,000	360	6/19/10	37
LZ 8	Ersatz Deutschland	683,000	486	46	18	11,000	360	3/30/11	37
LZ 9	Ersatz Z II	584,000	430	46	16	10,150	435	10/2/11	49.2
LZ 9		628,000	460	46	17	13,200	435		47.6
LZ 10	Schwaben	628,000	460	46	17	14,300	435	6/26/11	47.6
LZ 11	Viktoria Luise	660,000	486	46	18	14,300	510	2/14/12	50.5
LZ 12	Z III	628,000	460	46	17	14,300	435	4/25/12	47.6
LZ 13	Hansa	660,000	486	46	18	13,860	510	7/30/12	50
LZ 14	L 1	793,600	518.2	48.5	18	20,700	495	10/7/12	47.4
LZ 15	Ersatz Z I	690,000	466	48.5	16	18,080	510	1/16/13	51.6
LZ 16	Z IV	690,000	466	48.5	16	16,700	510	3/14/13	48.9

APPENDIX A (continued)

Builder's Name	Name or Number	Volume (cu.ft.) 100% Inflated	Length (ft.)	Diameter (ft.)	Gas Cell No.	Useful Lift (lb.)	Total H.P.	First Flight	Trial Speed (m.p.h.)
LZ 17	Sachsen	690,000	466	48.5	16	16,300	510	5/3/13	48.9
LZ 17		736,000	486	48.5	17	17,400	540		47.6
LZ 18	L 2	953,000	518.2	54.5	18	24,500	660	6/9/13	47
LZ 19	Ersatz E. Z I	690,000	466	48.5	16	15,850	495	6/6/13	45.5
LZ 20	Z V	690,000	466	48.5	16	15,850	495	7/8/13	46.6
LZ 20		736,000	486	48.5	17	16,700	540		45.5
LZ 21	Z VI	736,000	486	48.5	17	19,350	540	11/10/13	46.6
LZ 22	Z VII	780,000	510	48.5	18	19,500	540	1/8/14	45.5
LZ 23	Z VIII	780,000	510	48.5	18	19,500	540	2/21/14	45.5
LZ 24	L 3	794,500	518.2	48.5	18	20,250	630	5/11/14	47.4
LZ 25	Z IX	794,500	518.2	48.5	18	20,250	630	7/29/14	50.9
LZ 26	Z XII	880,000	528.5	52.5	15	26,950	630	12/14/14	51.1
LZ 27	L 4	794,500	518.2	48.5	18	20,100	630	8/28/14	51.4
LZ 28	L 5	794,500	518.2	48.5	18	20,250	630	9/22/14	52.1
LZ 29	Z X	794,500	518.2	48.5	18	20,250	630	10/13/14	50.9
LZ 30	Z XI	794,500	518.2	48.5	18	20,250	630	11/11/14	50.9
LZ 31	L 6	794,500	518.2	48.5	18	19,150	630	11/3/14	52
LZ 32	L 7	794,500	518.2	48.5	18	18,500	630	11/20/14	52
LZ 33	L 8	794,500	518.2	48.5	18	18,850	630	12/17/14	52
LZ 34	LZ 34	794,500	518.2	48.5	18	20,250	630	1/6/15	50.9
LZ 35	LZ 35	794,500	518.2	48.5	18	20,250	630	1/11/15	50.9
LZ 36	L 9	879,500	529.3	52.5	15	24,365	630	3/8/15	52.8
LZ 37	LZ 37	794,500	518.2	48.5	18	20,250	630	2/28/15	50.9
LZ 38	LZ 38	1,126,400	536.5	61.3	16	33,100	840	4/3/15	56.6
LZ 39	LZ 39	879,500	529.3	52.5	15	22,100	630	4/24/15	51
LZ 40	L 10	1,126,400	536.5	61.3	16	35,000	840	5/13/15	57.7
LZ 41	L 11	1,126,400	536.5	61.3	16	34,800	840	6/7/15	57
LZ 42	LZ 72	1,126,400	536.5	61.3	16	30,800	840	6/15/15	59.6

APPENDIX A (continued)

Builder's Name	Name or Number	Volume (cu.ft.) 100% Inflated	Length (ft.)	Diameter (ft.)	Gas Cell No.	Useful Lift (lb.)	Total H.P.	First Flight	Trial Speed (m.p.h.)
LZ 43	L 12	1,126,400	536.5	61.3	16	34,900	840	6/21/15	59.5
LZ 44	LZ 74	1,126,400	536.5	61.3	16	35,700	840	7/8/15	61.6
LZ 45	L 13	1,126,400	536.5	61.3	16	34,250	840	7/23/15	59.7
LZ 46	L 14	1,126,400	536.5	61.3	16	33,800	840	8/9/15	59.2
LZ 47	LZ 77	1,126,400	536.5	61.3	16	35,700	840	8/24/15	61.6
LZ 48	L 15	1,126,400	536.5	61.3	16	34,600	960	9/9/15	59.7
LZ 49	LZ 79	1,126,400	536.5	61.3	16	35,700	840	8/2/15	61.6
LZ 50	L 16	1,126,400	536.5	61.3	16	34,200	960	9/23/15	59.7
LZ 51	LZ 81	1,126,400	536.5	61.3	16	35,700	960	10/7/15	61.6
LZ 51		1,264,100	585.5	61.3	18	39,500	960		60.1
LZ 52	L 18	1,126,400	536.5	61.3	16	33,800	960	11/3/15	59.7
LZ 53	L 17	1,126,400	536.5	61.3	16	33,100	960	10/20/15	58.1
LZ 54	L 19	1,126,400	536.5	61.3	16	33,700	960	11/27/15	60.4
LZ 55	LZ 85	1,126,400	536.5	61.3	16	35,700	840	9/12/15	61.6
LZ 56	LZ 86	1,126,400	536.5	61.3	16	35,700	840	10/10/15	61.6
LZ 56		1,264,100	585.5	61.3	18	39,500	840		60.1
LZ 57	LZ 87	1,126,400	536.5	61.3	16	35,700	960	12/6/15	61.6
LZ 57		1,264,100	585.5	61.3	18	39,500	960		60.1
LZ 58	LZ 88	1,126,400	536.5	61.3	16	35,700	840	11/14/15	61.6
LZ 58	L 25	1,264,100	585.5	61.3	18	39,500	960		60.1
LZ 59	L 20	1,264,100	585.5	61.3	18	39,250	960	12/21/15	55.7
LZ 60	LZ 90	1,126,400	536.5	61.3	16	35,700	960	1/1/16	61.6
LZ 60		1,264,100	585.5	61.3	18	39,500	960		60.5
LZ 61	LZ 21	1,264,100	585.5	61.3	18	38,800	960	1/10/16	57.5
LZ 62	L 30	1,949,600	649.6	78.5	19	61,600	1440	5/28/16	62.2
LZ 63	LZ 93	1,126,400	536.5	61.3	16	35,700	840	2/23/16	61.6
LZ 63		1,264,100	585.5	61.3	18	39,500	840		60.5
LZ 64	L 22	1,264,100	585.5	61.3	18	38,600	960	3/2/16	59

APPENDIX A (continued)

Builder's Name	Name or Number	Volume (cu.ft.) 100% Inflated	Length (ft.)	Diameter (ft.)	Gas Cell No.	Useful Lift (lb.)	Total H.P.	First Flight	Trial Speed (m.p.h.)
LZ 65	LZ 95	1,264,100	585.5	61.3	18	33,800	960	1/31/16	60
LZ 66	L 23	1,264,100	585.5	61.3	18	40,700	960	4/8/16	57.3
LZ 67	LZ 97	1,264,100	585.5	61.3	18	40.100	960	4/4/16	60
LZ 68	LZ 98	1,264,100	585.5	61.3	18	40,100	960	4/28/16	60
LZ 69	L 24	1,264,100	585.5	61.3	18	40,300	960	5/20/16	57.3
LZ 71	LZ 101	1,264,100	585.5	61.3	18	40,100	960	6/29/16	60
LZ 72	L 31	1,949,600	649.6	78.5	19	62,500	1440	7/12/16	63.8
LZ 73	LZ 103	1,264,100	585.5	61.3	18	40,100	960	8/8/16	60
LZ 74	L 32	1,949,600	649.6	78.5	19	64,900	1440	8/4/16	62.6
LZ 75	L 37	1,949,600	644.7	78.5	19	62,400	1440	11/9/16	63
LZ 76	L 33	1,949,600	644.7	78.5	19	66,100	1440	8/30/16	64.2
LZ 77	LZ 107	1,264,100	585.5	61.3	18	40,100	960	10/16/16	60
LZ 78	L 34	1,949,600	644.7	78.5	19	68,600	1440	9/22/16	64
LZ 79	L 41	1,949,600	644.7	78.5	19	62,900	1440	1/15/17	63.5
LZ 79							1200		
LZ 80	L 35	1,949,600	644.7	78.5	19	67,900	1440	10/12/16	64.2
LZ 80						74,584	1200		
LZ 81	LZ 111	1,264,100	585.5	61.3	18	40,100	960	12/20/16	60
LZ 82	L 36	1,949,600	644.7	78.5	19	71,600	1440	11/1/16	64
LZ 82						75,139	1200		
LZ 83	LZ 113	1,949,600	644.7	78.5	19	71,600	1440	2/22/17	65
LZ 84	L 38	1,949,600	644.7	78.5	19	71,550	1440	11/22/16	64.2
LZ 85	L 45	1,949,600	644.7	78.5	19	68,800	1200	4/2/17	64.2
LZ 86	L 39	1,949,600	644.7	78.5	19	71,600	1440	12/11/16	63.5
LZ 86						76,734	1200		
LZ 87	L 47	1,949,600	644.7	78.5	19	70,600	1200	5/11/17	63.4
LZ 88	L 40	1,949,600	644.7	78.5	19	71,600	1440	1/3/17	62.4
LZ 88						76,808	1200		

APPENDIX A (continued)

Builder's Name	Name or Number	Volume (cu.ft.) 100% Inflated	Length (ft.)	Diameter (ft.)	Gas Cell No.	Useful Lift (lb.)	Total H.P.	First Flight	Trial Speed (m.p.h.)
LZ 89	L 50	1,949,600	644.7	78.5	18?	70,800	1200	6/9/17	62.6
LZ 90	LZ 120	1,949,600	644.7	78.5	19	71,600	1440	1/31/17	65
LZ 91	L 42	1,959,700	644.7	78.5	18	78,900	1200	2/21/17	62
LZ 92	L 43	1,959,700	644.7	78.5	18	80,300	1200	3/6/17	62
LZ 93	L 44	1,959,700	644.7	78.5	18	83,400	1200	4/1/17	64.5
LZ 94	L 46	1,970,300	644.7	78.5	18	83,400	1200	4/24/17	64.2
LZ 95	L 48	1,970,300	644.7	78.5	18	85,800	1200	5/22/17	66.9
LZ 96	L 49	1,970,300	644.7	78.5	18	87,200	1200	6/13/17	65.8
LZ 97	L 51	1,970,300	644.7	78.5	18	87,000	1200	7/6/17	66.1
LZ 98	L 52	1,970,300	644.7	78.5	18	86,600	1200	7/14/17	66.4
LZ 98							1225		
LZ 99	L 54	1,970,300	644.7	78.5	18	87,100	1200	8/13/17	66.6
LZ 99							1225		
LZ 100	L 53	1,977,360	644.7	78.5	14	89,200	1200	8/8/17	66
LZ 100							1225		
LZ 101	L 55	1,977,360	644.7	78.5	14	89,600	1200	9/1/17	64.6
LZ 102	L 57	2,418,700	743	78.5	16	114,700	1200	9/26/17	64.0
LZ 103	L 56	1,977,360	644.7	78.5	14	85,100	1200	9/24/17	66
LZ 103							1225		
LZ 104	L 59	2,418,700	743	78.5	16	114,400	1200	10/10/17	64
LZ 105	L 58	1,977,360	644.7	78.5	14	87,200	1225	10/29/17	66.5
LZ 106	L 61	1,977,360	644.7	78.5	14	85,000	1225	12/12/17	68.9
LZ 107	L 62	1,977,360	644.7	78.5	14	85,500	1225	1/19/18	66.8
LZ 108	L 60	1,977,360	644.7	78.5	14	85,200	1225	12/18/17	66.1
LZ 109	L 64	1,977,360	644.7	78.5	14	86,100	1225	3/11/18	66
LZ 110	L 63	1,977,360	644.7	78.5	14	87,000	1225	3/4/18	71.6
LZ 111	L 65	1,977,360	644.7	78.5	14	86,200	1225	4/17/18	71.6
LZ 112	L 70	2,195,800	693.9	78.5	15	97,100	1715	7/1/18	81

APPENDIX A (continued)

Builder's Name	Name or Number	Volume (cu.ft.) 100% Inflated	Length (ft.)	Diameter (ft.)	Gas Cell No.	Useful Lift (lb.)	Total H.P.	First Flight	Trial Speed (m.p.h.)
LZ 113	L 71	2,195,800	693.9	78.5	15	98,500	1715	7/29/18	
LZ 113		2,418,700	743.2	78.5	16	112,700	1470		72.7
LZ 114	L 72	2,418,700	743.2	78.5	16	112,700	1470	7/9/20	
LZ 120	Bodensee	706,200	393.3	61.3	11	22,000	980	8/20/19	82.4
LZ 120		795,000	426.1	61.3	12	25,350			80.5
LZ 121	Nordstern	795,000	426.1	61.3	12	25,350	930	6/8/21	80.5
LZ 126	ZR 3	2,762,100	658.3	90.7	14	101,430	2000	8/27/24	79.5
LZ 127	Graf Zeppelin	3,995,000	775	100	17	66,000	2650	9/18/28	69.5
LZ 129	Hindenburg	7,062,100	803.8	135.1	16	224,200	4200	3/4/36	82.6
LZ 130	Graf Zeppelin II	7,062,100	803.8	135.1	16	224,200	4200	9/14/38	82.6
		Schütte-Lanz (Luftschiffbau Schütte-Lanz G.M.B.H.)							
SL 1	SL 1	734,500	432	60.5	7	11,000	480	10/17/11	44.5
SL 2	SL 2	861,900	474	59.8	15	17,300	740	2/28/14	55
SL 2		931,600	513.3	59.8	16	22,800	840		55.5
SL 3	SL 3	1,143,500	502.3	64.8	17	31,300	840	2/4/15	52.6
SL 4	SL 4	1,146,500	502.3	64.8	17	30,800	840	4/25/15	52.8
SL 5	SL 5	1,146,500	502.3	64.8	17	30,800	840	5/21/15	52.5
SL 6	SL 6	1,240,300	534.5	64.8	18	34,750	840	9/19/15	57.9
SL 7	SL 7	1,240,300	534.5	64.8	18	34,600	840	9/3/15	58.9
SL 8	SL 8	1,369,300	570.8	65.9	19	42,500	840	3/30/16	56.1
SL 9	SL 9	1,369,300	570.8	65.9	19	43,200	960	5/24/16	
SL 10	SL 10	1,369,300	570.8	65.9	19	47,400	960	5/17/16	58.8
SL 11	SL 11	1,369,300	570.8	65.9	19	47,400	960	8/2/16	58.8
SL 12	SL 12	1,369,300	570.8	65.9	19	47,400	960	11/9/16	58.8

APPENDIX A (continued)

Builder's Name	Name or Number	Volume (cu.ft.) 100% Inflated	Length (ft.)	Diameter (ft.)	Gas Cell No.	Useful Lift (lbs.)	Total H.P.	First Flight	Trial Speed (m.p.h.)
SL 13	SL 13	1,369,300	570.8	65.9	19	47,400	960	10/19/16	58.8
SL 14	SL 14	1,369,300	570.8	65.9	19	47,800	960	8/23/16	58.8
SL 15	SL 15	1,369,300	570.8	65.9	19	47,400	960	11/9/16	58.8
SL 16	e 9	1,369,300	570.8	65.9	19	47,400	960	1/18/17	58.8
SL 17	e 10	1,369,300	570.8	65.9	19	47,000	960	3/22/17	58.8
SL 20	SL 20	1,989,700	651	75.3	19	78,200	1200	9/10/17	62.8
SL 21	f 2	1,989.700	651	75.3	19	77,500	1200	11/26/17	64.7
SL 22	SL 22	1,989,700	651	75.3	19	82.600	1200	6/5/18	64.7

British Rigid Airships

Builder's Name	Name or Number	Volume (cu.ft.) 100% Inflated	Length (ft.)	Diameter (ft.)	Gas Cell No.	Useful Lift (lbs.)	Total H.P.	First Flight	Trial Speed (m.p.h.)
No. 9	No. 9	890,000	526	53	17	8,520	720	11/27/16	42.5
No. 23	No. 23	940,000	535	53	18	13,400	1000	9/19/17	54.5
No. 24	No. 24	940,000	535	53	18	13,800	1000	10/27/17	54.5
No. 25	No. 25	940,000	535	53	18	13,000	1000	10/14/17	54.5
R 26	R 26	940,000	535	53	18	14,050	1000	3/20/18	54.5
R 27	R 27	990,600	539	53	18	16,800	1000	6/18	56.5
R 29	R 29	990,600	539	53	18	19,400	1000	6/18	56.5
R 31	R 31	1,535,000	614.7	64.8	21	37,000	1500	8/18	70
R 32	R 32	1,535,000	614.7	64.8	21	37,000	1250	8/19	65
R 33	R 33	1,950,000	643	78.8	19	58,100	1250	3/6/19	60
R 34	R 34	1,950,000	643	78.8	19	58,100	1250	3/14/19	60
R 36	G-FAAF	2,101,000	675	78.8	20	35,900	1540	4/1/21	65
R 38	R 38	2,724,000	699	85.5	14	102,144	2100	6/23/21	71.3
	ZR 2								
R 80	R 80	1,200,000	535	70	15	39,900	920	7/19/20	60
R 100	R 100	5,156,000	709	133	15	114,000	3960	12/16/29	81
R 101	R 101	4,998,000	732	132	16	78,500	2925	10/14/29	?
R 101		5,508,800	777	132	17	103,000			

APPENDIX A (continued)

Builder's Name	Name or Number	Volume (cu.ft.) 100% Inflated	Length (ft.)	Diameter (ft.)	Gas Cell No.	Useful Lift (lbs.)	Total H.P.	First Flight	Trial Speed (m.p.h.)
		United States Built Rigid Airships (lift with 95% full)							
ZR 1	Shenandoah	2,235,000	680.3	78.7	20	53,600	1800	9/4/23	68.4
ZR 1						47,500	1500		62
ZRS 4	Akron	6,850,000	785	132.9	12	160,170	4480	9/23/31	79.5
ZRS 5	Macon	6,850,000	785	132.9	12	173,000	4480	4/21/33	87.2
			French Built Rigid Airship						
Spiess	Spiess	451,000	370	44.5	14	?	200	4/3/13	
Spiess		580,000	469	44.5	17		400		43.5

Source: Douglas H. Robinson, Giants in the Sky (Seattle: University of Washington Press, 1973), pp. 330-43.

APPENDIX B

FINAL DISPOSITIONS OF RIGID AIRSHIPS

Builder's Number	Name or Number	Remarks
		Zeppelins (Luftschiffbau Zeppelin G.M.B.H.)
LZ 1		Dismantled after 3 flights, early 1901
LZ 2		On second flight 1/17/06 force landed at Kisslegg, dismantled
LZ 3	Z I	Lengthened autumn 1908; dismantled at Metz, autumn 1913
LZ 4		Burned at Echterdingen, 8/5/08
LZ 5	Z II	Wrecked at Weilburg, 4/25/10
LZ 6		Lengthened spring 1910; burned 9/14/10 in shed at Oos
LZ 7	Deutschland	6/28/10, crashed in the Teutoberg Forest
LZ 8	Ersatz Deutschland	5/16/11, wrecked at Düsseldorf
LZ 9	Ersatz Z II	8/1/14, dismantled at Gotha, obsolete
LZ 10	Schwaben	6/28/12, burned on field at Düsseldorf
LZ 11	Viktoria Luise	Dismantled autumn 1915
LZ 12	Z III	Dismantled at Metz, summer 1914
LZ 13	Hansa	Dismantled at Johannisthal, summer 1916
LZ 14	L I	9/9/13, lost in storm off Heligoland, 14 dead
LZ 15	Ersatz Z I	3/19/13, wrecked by storm after forced landing at Karlsruhe
LZ 16	Z IV	Dismantled at Jüterbog, autumn 1916
LZ 17	Sachsen	Dismantled at Düren, autumn 1916
LZ 18	L 2	10/17/13, burned in air at Johannisthal, 28 dead
LZ 19	Ersatz E. Z I	6/13/14, forced landing at Diedenhofen, wrecked
LZ 20	Z V	8/27/14, shot down by A. A. fire, Mlawa, Poland

APPENDIX B (continued)

Builder's Number	Name or Number	Remarks
LZ 21	Z VI	8/6/14, damaged by gunfire at Liege, crashed near Bonn
LZ 22	Z VII	8/23/14, shot down by A. A. fire, St. Quirin, Lorraine, France
LZ 23	Z VIII	3/23/14, shot down by A. A. fire, Badonviller, Vosgues, France
LZ 24	L 3	2/17/15, forced landing on Fanö I., Denmark, 16 interned
LZ 25	Z IX	10/8/14, bombed by British aircraft in Düsseldorf shed
LZ 26	Z XII	8/8/17, dismantled at Jüterbog
LZ 27	L 4	2/17/15, forced landing at Blaavands Huk, Denmark, 11 interned, 4 missing
LZ 28	L 5	8/6/15, forced landing due A. A. fire over Dunamünde, Russia
LZ 29	Z X	3/21/15, forced landing at St. Quirin, France, due A. A. fire
LZ 30	Z XI	5/20/15, blew away from shed at Posen, burned
LZ 31	L 6	9/16/16, burned accidentally in Fuhlsbüttel shed
LZ 32	L 7	4/15/16, shot down off Horns Reef by British cruisers, 11 dead, 7 prisoners
LZ 33	L 8	Crashed at Tirlemort, Belgium, due A. A. fire over Nieuport, 3/5/15
LZ 34	LZ 34	5/21/15, forced landing at Insterburg, E. Prussia, due A. A. fire, burned.
LZ 35	LZ 35	4/13/15, forced landing Poperinghe, Belgium, due A. A. fire
LZ 36	L 9	9/16/16, burned accidentally in Fuhlsbüttel shed
LZ 37	LZ 37	6/7/15, brought down in flames by British aircraft, Ghent, Belgium, 9 dead, 1 survivor
LZ 38	LZ 38	6/7/15, bombed by British aircraft in Evere shed
LZ 39	LZ 39	12/18/15, forced landing near Kovno, Russia, due A. A. fire
LZ 40	L 10	9/3/15, burned in thunderstorm off Neuwerk I., 19 dead
LZ 41	L 11	April 1917, dismantled at Hage
LZ 42	LZ 72	2/26/17, dismantled at Jüterbog
LZ 43	L 12	8/10/15, burned at Ostend after A. A. damage in raid on England
LZ 44	LZ 74	10/8/15, rammed a mountain in the Schnee Eifel
LZ 45	L 13	April 1917, dismantled at Hage
LZ 46	L 14	6/23/19, wrecked by airship crews at Nordholz
LZ 47	LZ 77	2/21/16, shot down in flames by A. A. guns at Revigny, 11 dead

APPENDIX B (continued)

Builder's Number	Name or Number	Remarks
LZ 48	L 15	4/1/16, brought down by A. A. fire in Thames Estuary, 1 dead, 17 prisoners
LZ 49	LZ 79	1/30/16, crashed at Ath, Belgium, due A. A. fire in raid on Paris
LZ 50	L 16	10/19/17, wrecked at Nordholz by a crew in training
LZ 51	LZ 81	9/27/16, forced landing at Tirnova, Bulgaria, due A. A. fire
LZ 52	L 18	11/17/15, burned accidentally in Tondern shed, 1 dead, 7 injured
LZ 53	L 17	12/28/16, burned accidentally in Tondern shed
LZ 54	L 19	2/1/16, lost in North Sea after raid on England, 16 dead
LZ 55	LZ 85	5/5/16, brought down at Salonika by A. A. fire
LZ 56	LZ 86	9/4/16, wrecked in landing at Temesvar, 9 dead
LZ 57	LZ 87	7/28/17, dismantled at Jüterbog
LZ 58	LZ 88, L 25	9/15/17, dismantled at Postdam
LZ 59	L 20	5/3/16, wrecked in Norway after raid on England
LZ 60	LZ 90	11/7/16, blew away unmanned from Wittmundhaven in storm
LZ 61	LZ 21	11/28/16, shot down in flames off Yarmouth by British aircraft, 17 dead
LZ 62	L 30	Summer 1920, dismantled at Seerappen
LZ 63	LZ 93	Summer 1917, dismantled at Trier
LZ 64	L 22	5/14/17, shot down in flames off Terschelling by British aircraft, 21 dead
LZ 65	LZ 95	2/22/16, crash-landed outside Namur base due A. A. gunfire damage
LZ 66	L 23	8/21/17, shot down in flames off Lyngvig by British aircraft, 18 dead
LZ 67	LZ 97	7/5/17, dismantled in Jüterbog
LZ 68	LZ 98	August 1917, dismantled in Schneidemühl
LZ 69	L 24	12/28/16, burned accidentally entering Tondern shed
LZ 71	LZ 101	September 1917, dismantled in Jüterbog
LZ 72	L 31	10/2/16, shot down in flames at Potters Bar by British aircraft, 19 dead
LZ 73	LZ 103	August 1917, dismantled in Königsberg

APPENDIX B (continued)

Builder's Number	Name or Number	Remarks
LZ 74	L 32	September 24, 1916, shot down in flames at Billericay by British aircraft, 22 dead
LZ 75	L 37	Summer 1920, broken up at Seddin
LZ 76	L 33	9/24/16, forced down at Little Wigborough by A. A. fire, 22 prisoners
LZ 77	LZ 107	July 1917, dismantled in Darmstadt
LZ 78	L 34	11/28/16, shot down in flames off West Hartlepool by British aircraft, 20 dead
LZ 79	L 41	6/23/19, wrecked by airship crews at Nordholz
LZ 80	L 35	11/15/18, broken up at Jüterbog
LZ 81	LZ 111	8/10/17, dismantled at Dresden
LZ 82	L 36	2/7/17, lost in forced landing at Rehben-an-der-Aller
LZ 83	LZ 113	10/8/20, surrendered to France; dismantled at Maubeuge
LZ 84	L 38	12/29/16, wrecked in forced landing at Seemuppen, Russia
LZ 85	L 45	10/20/17, forced landing at Sisteron, France, 17 prisoners
LZ 86	L 39	3/17/17, shot down in flames by A. A. fire at Compiègne, 17 dead
LZ 87	L 47	1/5/18, destroyed in Ahlhorn explosion
LZ 88	L 40	6/17/17, wrecked in forced landing at Neuenwald
LZ 89	L 50	10/20/17, lost fore gondola at Dammartin, France; ship lost in Mediterranean, 4 dead, 16 prisoners
LZ 90	LZ 120	12/25/20, surrendered to Italy; dismantled at Ciampino, June 1921
LZ 91	L 42	6/23/19, wrecked by airship crews at Nordholz
LZ 92	L 43	6/14/17, shot down in flames off Vlieland by British aircraft, 24 dead
LZ 93	L 44	10/20/17, shot down in flames by A. A. fire at St. Clement, 18 dead
LZ 94	L 46	1/5/18, destroyed in Ahlhorn explosion
LZ 95	L 48	6/17/17, shot down in flames at Theberton by British aircraft, 14 dead, 3 survivors
LZ 96	L 49	10/20/17, forced landing at Bourbonne-les-Bains, 19 prisoners
LZ 97	L 51	1/5/18, destroyed in Ahlhorn explosion

APPENDIX B (continued)

Builder's Number	Name or Number	Remarks
LZ 98	L 52	6/23/19, wrecked by airship crews at Wittmund
LZ 99	L 54	7/19/18, burned in Tondern shed in British air attack
LZ 100	L 53	8/11/18, shot down in flames off Terschelling by British aircraft, 19 dead
LZ 101	L 55	10/20/17, forced landing at Tiefenort-an-der-Werra, dismantled
LZ 102	L 57	10/8/17, wrecked and burned at Jüterbog
LZ 103	L 56	6/23/19, wrecked by airship crews at Wittmund
LZ 104	L 59	4/7/18, burned in air over straits of Otranto, 23 dead
LZ 105	L 58	1/5/18, destroyed in Ahlhorn explosion
LZ 106	L 61	8/29/20, surrendered to Italy, wrecked at Ciampino, January 1921
LZ 107	L 62	5/10/18, lost in accidental explosion off Heligoland
LZ 108	L 60	7/19/18, burned in Tondern shed in British air attack
LZ 109	L 64	7/21/20, surrendered to England; dismantled at Pulham 6/21/21
LZ 110	L 63	6/23/19, wrecked by airship crews at Nordholz
LZ 111	L 65	6/23/19, wrecked by airship crews at Nordholz
LZ 112	L 70	8/5/18, shot down in flames off Cromer by British aircraft, 22 dead
LZ 113	L 71	7/1/20, surrendered to England; dismantled at Pulham 1923
LZ 114	L 72	7/13/20, surrendered to France; 12/21/23, exploded off Sicily, 50 dead
LZ 120	Bodensee	7/3/21, surrendered to Italy; dismantled July 1928
LZ 121	Nordstern	6/13/21, surrendered to France; dismantled September 1926
LZ 126	ZR 3	6/30/32, decommissioned, dismantled at Lakehurst December 1939
LZ 127	Graf Zeppelin	Spring 1940, dismantled at Frankfurt
LZ 129	Hindenburg	5/6/37, burned at Lakehurst, 35 dead, 61 survivors
LZ 130	Graf Zeppelin II	Spring 1940, dismantled at Frankfurt

APPENDIX B (continued)

Builder's Number	Name or Number	Remarks
		Schütte-Lanz (Luftschiffbau Schütte-Lanz G.M.B.H.)
SL 1	SL 1	7/16/13, wrecked in storm at Schneidemühl
SL 2	SL 2	1/10/16, wrecked in storm at Luckenwalde
SL 3	SL 3	5/1/16, crashed in Baltic off Gotland
SL 4	SL 4	12/11/15. wrecked by storm in Seddin shed
SL 5	SL 5	7/5/15, wrecked by storm at Giessen
SL 6	SL 6	11/18/15, exploded in air near Seddin, 20 dead
SL 7	SL 7	3/6/17, dismantled at Jüterbog
SL 8	SL 8	11/20/17, dismantled at Seddin
SL 9	SL 9	3/30/17, burned in air off Pillau, 23 dead
SL 10	SL 10	7/28/16, disappeared in Black Sea, 16 dead
SL 11	SL 11	9/3/16, shot down in flames over London by British aircraft, 16 dead
SL 12	SL 12	12/28/16, wrecked in landing at Ahlhorn
SL 13	SL 13	2/8/17, burned in collapse of Leipzig shed
SL 14	SL 14	5/11/17, broke in two in landing at Wainoden, dismantled
SL 15	SL 15	8/17, dismantled at Sandhofen
SL 16	e 9	8/17, dismantled at Spich
SL 17	e 10	8/17, dismantled at Allenstein
SL 20	SL 20	1/5/18, destroyed in Ahlhorn explosion
SL 21	f 2	2/18, dismantled at Zeesen
SL 22	SL 22	6/20, dismantled at Jüterbog
		British Rigid Airships
No. 9	No. 9	6/18, dismantled at Pulham
No. 23	No. 23	9/19, dismantled at Pulham
No. 24	No. 24	12/19, dismantled at Pulham
No. 25	No. 25	9/19, dismantled at Cranwell

APPENDIX B (continued)

Builder's Number	Name or Number	Remarks
R 26	R 26	3/10/19, dismantled
R 27	R 27	8/16/18, burned in shed at Howden
R 29	R 29	10/24/19, dismantled at East Fortune
R 31	R 31	7/19, broken up at Howden
R 32	R 32	4/27/21, broken up at Howden
R 33	R 33	1928, dismantled
R 34	R 34	1/27/21, wrecked at Howden
R 36	G-FAAF	1926, dismantled at Pulham
R 38	R 38, ZR 2	8/24/21, broke up over Hull and burned, 44 dead
R 80	R 80	1925, dismantled at Pulham
R 100	R 100	1931, dismantled at Cardington
R 101	R 101	10/5/30, crashed and burned at Beauvais, France, 48 dead
	United States Built Rigid Airships (lift with helium 95% full)	
ZR 1	Shenandoah	9/3/25, broke up in air at Ava, Ohio, 14 dead, 29 survivors
ZRS 4	Akron	4/3/33, crashed at sea, off Barnegat, 73 dead, 3 survivors
ZRS 5	Macon	2/12/35, crashed at sea off Point Sur, 2 dead, 81 survivors
	French Built Rigid Airship	
Spiess	Spiess	1914, dismantled

Source: Douglas H. Robinson, Giants in the Sky (Seattle: University of Washington Press, 1973), pp. 330-43.

SELECTED BIBLIOGRAPHY

I. Important Works

Gilfillan, S. Colum. The Sociology of Invention. Cambridge, Mass.: M. I. T. Press, 1970.

__________. Supplement to the Sociology of Invention. San Francisco: San Francisco Press, 1971.

List, Friedrich. National System of Political Economy. Translated by Samson S. Lloyd. London: Longmans, Green & Co., 1909.

Melko, Matthew. "The Interaction of Civilizations: An Essay." Journal of World History, Vol. XI, No. 4 (1969).

Needham, Joseph, and Ling, Wang. Science and Civilization in China. Vol. IV, part II. Cambridge: University Press, 1965.

Sorokin, Pitirim A. Social and Cultural Dynamics. Vol. II. New York: Bedminster Press, 1962.

Toynbee, Arnold J. A Study of History. Vols. II, IV, V. London: Oxford University Press, 1961.

__________. A Study of History. 2nd ed. Vol. II. London: Oxford University Press, 1961.

__________. A Study of History. Vol. VIII. London; Oxford University Press, 1939.

II. Primary Sources

A. Archival and documentary materials

Germany, Militärgeschichtlichen Forschungsamt. Die deutschen Luftstreitkräfte von ihrer Entstehung bis zum Ende des Weltkrieges 1918, Die Militärluftfahrt bis zum Beginn des Weltkrieges 1914, Anlageband. Freiburg im Breisgau: E. S. Mittler, 1965.

Great Britain, Admiralty, Air Department. *Handbook on Rigid Airship No. 1* (confidential). London: HMSO, 1913.

Great Britain, Air Ministry, Aeronautical Research Committee, Accidents Investigation Sub-Committee. *Report on the Accident to H. M. Airship R 38.* January, 1922. *Reports and Memoranda*, #775. London: HMSO, May, 1922.

Great Britain, Air Ministry, Aeronautical Research Committee, J. R. Pannell, R. A. Frazer, and H. Bateman. *Experiments on Rigid Airship R 32*, Parts I-III. *Reports and Memoranda*, No. 811-3. Aeronautics 62-4, February - May, 1921. London: HMSO, 1923.

Great Britain, Air Ministry. "Airships for Commercial Purposes." *Flight*, Vol. XI (January 30, 1919).

__________. *Report of the R 101 Inquiry*. London: HMSO, 1931.

Great Britain, Parliament. *Parliamentary Papers*. House of Commons & Command, 1924-5, Vol. XXXI. Accounts & Papers, Vol. 16, Cmd. 2525.

National Archives. Record Group 72. Chief of Naval Operations Files.

__________. "Tambach Archives." Kriegsarchiv der Marine.

Statutes at Large, XLIV, Part II, Chapter 344 (1925-7). *Air Commerce Act of 1926*.

Statutes at Large, Vol. XLI, Ch. 9 (1919-21), *An Act Making Appropriations for the Naval Service for the Fiscal Year Ending June 30, 1920, and for Other Purposes*.

Statutes at Large, XLIV, Part II, Chapter 355 (1925-7). *An Act To Amend the Act entitled "An Act authorizing the conservation, production, and exploitation of helium gas, a mineral resource pertaining to the national defense and to the development of commercial aeronautics, and for other purposes*.

United States Navy. Bureau of Aeronautics. "Constructive Recommendations by *Shenandoah* Court." *U.S. Air Services*, Vol. XI, No. 2 (February, 1926).

United States, Department of State. Papers Relating to the Foreign Relations of the United States, 1921. Vol. II. Washington: United States Government Printing Office, 1936.

__________. The Treaty of Versailles and After: Annotations of the Text of the Treaty. Washington: United States Government Printing Office, 1947.

B. Contemporary works by participants or close observers

1. Books

Burgess, Charles P. Airship Design. New York: The Ronald Press Co., 1927.

Curtis, Thomas E. "The Zeppelin Airship." Smithsonian Institute Annual Report, 1900. Washington: Smithsonian Institute, 1901.

Deutsche Luftschiffahrt-Aktien-Gesellschaft. Passagier-Fahrten mit Zeppelin Luftschiffen. Hamburg: n.p. (DELAG), 1911.

Eckener, Hugo. Graf Zeppelin. Stuttgart: J. G. Cott'sche Buchhandlung Nachfolger, 1938.

__________. Das Werk des Grafen Zeppelin. Frankfurt a/M: M. Diesterweg, 1930.

Litchfield, Paul W. The Story of the Airship. Akron, Ohio: n.p., n.d.

Luftschiffbau Zeppelin. Der Luftschiffbau Zeppelin und sein Tochtergesellschaften. Berlin: M. Schroder, n.d.

__________. Das Werk Zeppelins, Eine Festgabe zu seinem 75. Geburtstag. Stuttgart: Kommissionsverlag Julius Hoffman, 1913.

Rosendahl, Charles. What About the Airship? New York: Charles Scribner's Sons, 1938.

2. Articles

Arnstein, Karl. "The Development of Large Commercial Airships." Transactions, American Society of Mechanical Engineers, Vol. L (1928).

__________. "Why Airships?: U.S. Air Services, Vol. XVII, No. 12 (December, 1932).

Burgess, Charles P. "Airships as Cruisers." U.S. Air Services, Vol. XX, No. 10 (October, 1935).

__________. "The Rigid Airship ZR-3." Journal of the American Society of Naval Engineers, Vol. XXXVI, No. 4 (November, 1924).

Burgess, Charles P.; Hunsaker, Jerome C.; and Truscott, Starr. "The Strength of Rigid Airships." Journal of the Royal Aeronautical Society, Vol. XXVIII, No. 162 (June, 1924).

d'Arlandes, François-Laurent. "The First Aerial Voyage." Lighter-Than-Air Flight. Edited by C. V. Glines. New York: Franklin Watts, Inc., 1965.

Eckener, Hugo. "The Case of the Airship. II. - Dirigibles Can Successfully Compete with Aeroplanes for Speed, Safety, and Regularity." Airways, Vol. IV, No. 56 (January, February, 1928).

__________. "Modern Zeppelin Airships." Aero Digest, Vol. VI, No. 5 (May, 1925).

Fulton, Garland. "Airship Progress and Airship Problems." Journal of the American Society of Naval Engineers, Vol. XLI, No. 1 (February, 1929).

__________. "Improved Airship Performance." Transactions, American Society of Mechanical Engineers, Vol. LVI (1934).

__________. "Rigid Airships." Part II. U.S. Naval Institute Proceedings, Vol. XLVII, No. 11 (November, 1921).

__________. "Some Features of a Modern Airship - U.S.S. Akron." Transactions, Society of Naval Architects and Marine Engineers, Vol. XXXIX (1931).

__________. "Some Matters Relating to Large Airships." Transactions, Society of Naval Architects and Marine Engineers, Vol. XXXII (1925).

Hunsaker, Jerome C. "Naval Airships," Transactions, Society of Automotive Engineers, Vol. XIV, Part I (1919).

__________. "The Navy's First Airships," U.S. Naval Institute Proceedings, Vol. LXV, No. 8 (August, 1919).

__________. "The Present Status of Airships in Europe," Journal of the Franklin Institute, Vol. LXXVII, No. 6 (June, 1914).

__________. "Use of Airships with the Fleet." U.S. Air Services, Vol. I, No. 3 (April, 1919).

Lehmann, Ernst A. "The Safety of the Zeppelin Airship." Mechanical Engineering, Vol. XLVIII, No. 2 (February, 1926).

__________. "Zeppelins Save the Germans at Jutland." Translated by Howard Mingos. World Today, Vol. LI (January, 1928).

Litchfield, Paul W. "Establishing an Airship-Building Industry in the United States." U.S. Air Services, Vol. XVII, No. 4 (April, 1932).

Maitland, Edward M. "The Commercial Future of Airships." Journal of the Royal Society of Arts, Vol. LXVIII, No. 3524 (June 4, 1920).

Moffett, William A. "Rigid Airship Building and Operation in this Country Originated with the U.S. Navy." Aeronautical Digest, Vol. III, No. 6 (December, 1923).

__________. "Rigid Airship Development and the U.S.S. Akron," National Aeronautic Magazine, Vol. X, No. 1 (January, 1932).

__________. "The U.S.S. Shenandoah." Aeronautical Digest, Vol. IV, No. 1 (January, 1924).

Renard, Charles. "Success at Last!" Lighter-Than-Air Flight. Edited by C. V. Glines. New York: Franklin Watts, Inc., 1965.

Richmond V. C. "The Aerial Liner." Journal of the Birmingham Meteorological Society, Vol. VIII, No. 9 (September 1, 1924).

__________. "Some Modern Developments in Rigid Airship Construction." The Engineer, Vol. CXLV, No. 3770 (April 13, 1928).

Rosendahl, Charles E. "U.S.S. Los Angeles." U.S. Naval Institute Proceedings, Vol. LVII, No. 6 (June, 1931).

Wallis, B. N. "Some Technical Aspects of the Commercial Airship." Engineer, Vol. CXLI, No. 3660 (February 19, 1926).

Wiley, Herbert V. "The Value of Naval Airships." U.S. Naval Institute Proceedings, Vol. LX, No. 5 (May, 1934).

C. Memoirs and diaries

Alexander, E. Porter. Military Memoirs of a Confederate. Bloomington, Ind.: Indiana University Press, 1962.

Berg, Carl. David Schwarz, Carl Berg, Graf Zeppelin: Ein Beitrag zur Entstehung der Zeppelin-Luftschiffahrt in Deutschland. Munich: By the Author, 1925.

Buttlar-Brandenfels, Horst Treusch von. "Die Aufgaben der Luftschiffe im Dienste der Marine." Unsere Luftstreitkräfte 1914-18. Edited by Walter von Eberhardt. Berlin: C. A. Weller, 1930.

__________. Zeppelins over England. Translated by Huntley Paterson. New York: Harcourt, Brace, 1932.

Colsman, Alfred. Luftschiff Voraus! Arbeit und erleben am werke Zeppelins. Stuttgart: Deutsche Verlags Anstalt, 1933.

du Plessis de Grenedan, Jean. Les grands dirigeables dans la paix et dans la guerre. Paris: Plon-Nourrit et Cie, 1925.

Eckener, Hugo. Im Zeppelin über Länder und Meere. Flensburg: Verlagshaus Christian Wolff, 1949.

Einem, Karl von. Errinerungen eines Soldaten 1853-1933. Leipzig: K. F. Koehler, 1933.

George, David Lloyd. War Memoirs of David Lloyd George, 1914-15. Boston: n.p., 1933.

Hacker, Georg. Die Männer von Manzell. Frankfurt am Main: Societäts-Druckerei, 1936.

Jellicoe, John. The Grand Fleet, 1914-16. London: Cassell & Co., 1919.

Lehmann, Ernst A., and Adelt, Leonhard. Auf Luftpatrouille und Weltfahrt. Berlin: Volksverband der Bucherfreunde Wegweiser-Verlag, 1936.

Ludendorff, Erich. The General Staff and Its Problems. I. Translated by F. A. Holt. New York: E. P. Dutton & Co., n.d. (1920).

Meager, George. My Airship Flights, 1915-1930. London: William Kimber, 1970.

Müller, Georg von. The Kaiser and His Court. Edited by Walter Gorlitz. Translated by Mervyn Savill. London: Macdonald & Co., 1961.

Müller-Breslau, Heinrich. "Zur Geschichte des Zeppelin-Luftschiffes." Verhandlung zur Beforderung des Gewerbfleisses. Berlin: n.p., 1914.

Pohl, Hugo von. Aus Aufzeichnungen und Briefen während der Kriegszeit. Berlin: K. Siegismund, n.d. (1920).

Scheer, Reinhard von. Germany's High Seas Fleet in the World War. New York: Peter Smith, 1934.

Schütte, Johann. "Vorwort." Der Luftschiffbau Schütte-Lanz 1909-25. Edited by Johann Schütte. Munich: Verlag Oldenbourg, 1926.

Shute, Nevil [Nevil Shute Norway]. Slide Rule: The Autobiography of an Engineer. New York: Ballantine Books, 1954.

Tirpitz, Alfred von. Memoirs. Vol. I. New York: Dodd, Mead, and Co., 1919.

D. Contemporary journal articles

Addinell, H. "Air Transport: Russia and Her Airships." Flight, Vol. XXIV, No. 49 (December 1, 1932).

"The Airship for the British Navy." Engineering, Vol. XCI (February 17, 1911).

Black, Archibald. "Leviathans of the Air." Aero Digest, Vol. VIII, No. 1 (January, 1926).

"The Commercial Possibilities of the Airship." The Engineer, Vol. CL, No. 3892 (August 15, 1930).

"The Development of Airship Transport." Aeronautical Engineering, Supplement to The Aeroplane, Vol. XXV, No. 11 (September 12, 1923).

Dienstbach, Carl. "The Wreck of the Deutschland." Scientific American, Vol. CIII (July 9, 1910).

"The Destruction of the Schwaben." Scientific American, Vol. CVII (1912).

Evans, E. "The Development and Future of the Airship." Journal of the Institution of Aeronautical Engineers, Vol. I, No. 5 (May, 1927).

"The Evolution of the Airship--(I)." Aeronautics, Vol. XVI, No. 297 (June 26, 1919).

"The Evolution of the British Naval Airship." Engineering, Vol. CVII, No. 2789 (June 13, 1919).

Fournier, Touchard, Le Bris, and Fayolle. "Le tragique voyage du Dixmude." L'Aerophile, Vol. XXXII, Nos. 3-4 (February 1-15, 1924).

"Schütte-Lanz-Luftschiffe für die Armee," Deutsche Zeitschrift für Luftschiffahrt, Vol. XVII, No. 5 (May, 1913).

III. Secondary Sources

A. Books

Abbott, Patrick. Airship. New York: Charles Scribner's Sons, 1973.

Cuneo, John R. Winged Mars, I, The German Air Weapon, 1870-1914. Harrisburg, Pa.: Military Service Publishers, 1942.

Fisher, John. Airlift 1870: The Balloon and Pigeon Post in the Siege of Paris. London: Max Parrish, 1965.

Gibbs-Smith, Charles H., ed. Aviation: An Historical Survey from Its Origin to the End of World War II. London: HMSO, 1970.

Gladisch, Walter. Der Krieg in der Nordsee. Vol. VI. Berlin: E. S. Mittler u. Sohn, 1937.

Glines, C. V., ed. Lighter-Than-Air Flight. New York: Franklin Watts, Inc., 1965.

Goldsmith, Margaret. Zeppelin: A Biography. New York: William Morrow & Co., 1931.

Guttery, T. E. Zeppelin, An Illustrated Life of Count Ferdinand von Zeppelin, 1838-1917. Aylesbury, Bucks, U. K.: Shire Publications Ltd., 1973.

Haydon, F. Stansbury. Aeronautics in the Union and Confederate Armies, with a Survey of Military Aeronautics Prior to 1861. Vol. I. Baltimore: Johns Hopkins Press, 1941.

Heiss, Friedrich. Das Zeppelin-Buch. Berlin: Volk und Reich Verlag, 1936.

Higham, Robin D. S. The British Rigid Airship, 1908-31. London: G. T. Foulis & Co., 1961.

Hildebrandt, A. Die Luftschifffahrt nach ihrer geschichtlichen und gegenwärtigen Entwicklung. Munich: R. Oldenbourg, 1910.

Hildebrandt, Hans, ed. Zeppelin-denkmal für das Deutsche Volk. Stuttgart: Germania-Verlag, 1925.

Hoehling, A. A. Who Destroyed the Hindenburg? Boston: Little, Brown & Co., 1962.

Hoehling, Mary. Thaddeus Lowe: America's One-Man Air Corps. Chicago: Kingston House, 1958.

Horton, Edward. The Age of the Airship. Chicago: Henry Regnery Co., 1973.

Jackson, Robert. Airships. Garden City, N.Y.: Doubleday & Co., 1973.

Keller, Charles L. U.S.S. Shenandoah. Boston: Commonwealth Publishing Co., 1965.

Kirschener, Edwin J. The Zeppelin in the Atomic Age. Urbana, Illinois: University of Illinois Press, 1957.

Leasor, James. The Millionth Chance: The Story of the R101. London: Hamish Hamilton, 1957.

Marion, Fulgence. Les ballons et les voyages aériens. Paris: Hachette & Co., 1881.

Marsh, William L. "The Evolution of Rigid Airship Design." Air Annual of the British Empire. Vol. II. London: Gale & Polden, 1930.

Mooney, Michael. The Hindenburg. New York: Dodd, Mead & Co., 1972.

Morpurgo, J. E. Barnes Wallis, A Biography. London: Longman Group, 1972.

Muller, Herbert J. The Children of Frankenstein: A Primer on Modern Technology and Human Values. Bloomington, Ind.: Indiana University Press, 1970.

Raleigh, Walter. The War in the Air. Vol. I. London: Oxford University Press, 1922.

Robinson, Douglas H. Giants in the Sky. Seattle: University of Washington Press, 1973.

__________. LZ 129 Hindenburg. New York: Arco Publishing Co., 1964.

__________. The Zeppelin in Combat. London: G. T. Foulis & Co., Ltd., 1966.

Rolt, L. T. C. The Aeronauts, A History of Ballooning, 1783-1903. New York: Walker & Co., 1966.

Saager, Adolf. Zeppelin. Stuttgart: Verlag Robert Lutz, 1915.

Seibel, Clifford W. Helium, Child of the Sun. Lawrence, Kansas: University Press of Kansas, 1969.

Sinclair, J. A. Airships in Peace and War. London: Rich & Cowan, 1934.

Smith, Richard K. The Airships Akron and Macon. Annapolis, Md.: U.S. Naval Institute, 1965.

Sprigg, Christopher. The Airship: Its Design, History, Operation and Future. London: Sampson, Low, Marston & Co., 1931.

Strahlmann, Fritz. Zwei deutsche Luftschiffhäfen des Weltkrieges Ahlhorn u. Wildeshausen. Edited by Fritz Strahlmann. Oldenburg: Oldenburg Verlagshaus, 1926.

Whitehouse, Archibald. The Zeppelin Fighters. London: Robert Hale, 1966.

B. Articles

Boothby, F. L. M. "Early Days of the R. N. Airship Section." The Airship, Vol. V, No. 19 (September-December, 1938.

Bryan, John Randolph. "Balloon Used for Scout Duty." Southern Historical Society Papers. Richmond: 1905.

Eberhardt, Walter von. "Die geschichtliche Entwicklung der Luftfahrt und die Bedeutung der Persönlichkeit fur dieselbe." Unsere Luftstreitkräfte, 1914-18. Edited by Walter von Eberhardt. Berlin: C. A. Weller, 1930.

Hylander, C. J. "Steam, Electric, and Man-Powered Dirigibles." Lighter-Than-Air Flight. Edited by C. V. Glines. New York: Franklin Watts, Inc., 1965.

Keller, Charles L. "The Hensley Affair." Journal of the American Aviation Historical Society, Vol. X, No. 4 (Winter, 1965).

Schiller, Hans von. "Count Zeppelin's American Balloon Ascent (IV)." Letter to A. D. Topping. Wingfoot Lighter-Than-Air Society Bulletin, XIII, No. 5 (March, 1966).

Squires, J. Duane. "Aeronautics in the Civil War." Letter from Cheves. American Historical Review, Vol. XLII (1937).

Topping, A. D. "Dr. Karl Arnstein," Buoyant Flight, the Bulletin of the Lighter-Than-Air Society, Vol. XXII, No. 3 (March - April 1975).

Wise, John. "The Birth of Flight," Lighter-Than-Air Flight. Edited by C. V. Glines. New York: Franklin Watts, Inc., 1965.

Wright, George E. "Germany's Giant Wooden Warriors," Air Classics, Vol. VIII, No. 4 (February, 1972).

BIOGRAPHICAL SKETCH

Price Bradshaw, Jr. was born on March 9, 1944, in Beaumont, Texas. In 1962 he was graduated from French High School in Beaumont, Texas, and that same year he enrolled in Rice University, Houston, Texas. In 1964, he transferred to Lamar University, Beaumont, Texas, from which he received his B.A. degree in history in 1966. He began graduate work in European history in the fall of 1966 at the University of Houston, Houston, Texas, where he was awarded a teaching fellowship for 1966-7 and a graduate assistantship for 1967-8. He obtained his M.A. degree in August 1968. In the fall of 1968, he commenced work toward the Ph.D. degree in modern European history at the University of Florida, Gainesville, Florida, where he was awarded several university fellowships and teaching assistantships. Price Bradshaw, Jr. is married to the former Miss Margaret Ann Ford of Beaumont, Texas.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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